TECHNICAL REPORT ON OPERATION TIMES FOR DUCT MOUNTED, CORROSION PROTECTED SPRINKLERS AND THE INFLUENCE OF SPRINKLER SPRAY ON HEATED AIR FLOW THROUGH DUCTING

Prepared by

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REPORT

on

SPECIAL SERVICES INVESTIGATION OF

Operation Times for Duct Mounted, Corrosion Protected Sprinklers and the Influence of Sprinkler Spray on Heated Air Flow Through Ducting

HSB Industrial Risk Insurers
Hartford, CT

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G E N E R A L

INTRODUCTION:

This Report describes a Special Services Investigation to determine operation times for duct mounted, corrosion protected sprinklers and the influence of sprinkler spray on heated air flow through ducting for HSB Industrial Risk Insurers.

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PURPOSE:

The sole purpose of the investigation was to record actuation times and air velocity test data of duct mounted corrosion protected sprinklers for HSB Industrial Risk Insurers.

This research project investigated the influence of various methods of corrosion protection on the actuation times of standard and quick response sprinklers. This investigation was conducted using both uncoated and corrosion protected sprinklers

mounted in a 12 inch diameter duct under specified test conditions of heating and air flow.

TEST FACILITY:

These fire tests were conducted in UL's Fire Test Building No. 3, located in Northbrook, IL.

The test facility used to conduct these tests is a nominal 40 ft. by 60 ft. room with a nominal 24 ft. ceiling.

The test room is equipped with an exhaust system vented to a smoke abatement system. The room was sealed to prevent air drafts which would adversely affect the growth and stability of the test fires.

PLAN:

This investigation consisted of conducting three tasks which are described as follows:

Task 1 - Determine differences in the operating times and apparent Response Time Index (RTI) of Listed sprinklers having fusible link or glass bulb heat responsive elements using a sprinkler sensitivity plunge oven.

Task 2 - Determine operation times for standard and quick response sprinklers having various corrosion protection methods inside a 12 inch diameter duct flowing heated air.

Task 3 - Determine the influence of sprinkler water discharge on the rate of air flow through the duct.

T E S T R E C O R D

GENERAL TEST CONDITIONS:

TASK 1: The sprinkler sensitivity plunge oven, as described in the Standard for Automatic Sprinklers for Fire Protection Service, UL199 was used for this testing. This oven consists of an 8 inch (203 mm) square stainless steel chamber and a heat source with an adjustable speed fan to circulate heated air past the sprinkler under test. The heated air flows through straightening vanes to provide a laminar air flow over the sprinkler under known velocity and temperature conditions.

TASK 2: A nominal 1 foot diameter galvanized steel duct with a 18 gauge wall thickness was utilized for the Task 2 and 3 tests. The duct was approximately 25 feet long and incorporated 6 positions for sprinklers as shown in Fig. 1 and Figs. 1 and 2, Appendix A. The sprinklers were positioned inside the duct through the use of removable plates which conformed to the curvature of the duct (see Fig. 1 and Fig. 3 and 14, Appendix A). These plates were manufactured from galvanized steel and had a thickness of 0.060 inch. A bulkhead fitting was used to attach the sprinkler to the curved plate. The plate was then positioned over a 2" diameter hole in the duct which accepted the sprinkler/curved plate. The pendent style sprinkler was installed perpendicular to the longitudinal axis of the duct. The positioning of the sprinkler had the deflector approximately 2-1/2 inches inside the duct (see Fig. 5, Appendix A).

A 12 inch by 12 inch by 8 inch deep pan, filled with a quantity of heptane was used to develop the heat necessary to activate the sprinklers (see Figs. 7 and 8 Appendix A). A 4 foot by 4 foot by 7 foot high, 5 sided enclosure was constructed around the pan to control the geometry of the resulting fire (see Figs. 1 and 4, Appendix A).

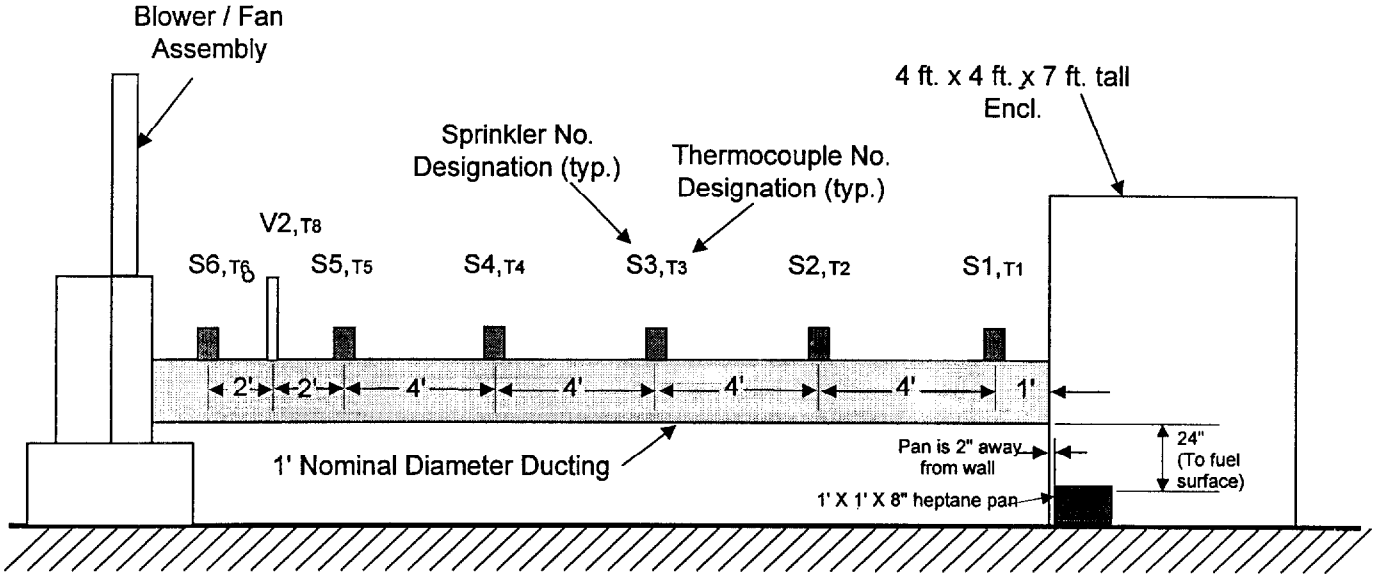
A blower / damper assembly attached to the downstream end of the duct was used to set the required velocities at a predetermined level prior to ignition of the test pan (see Fig. 2, Appendix A).

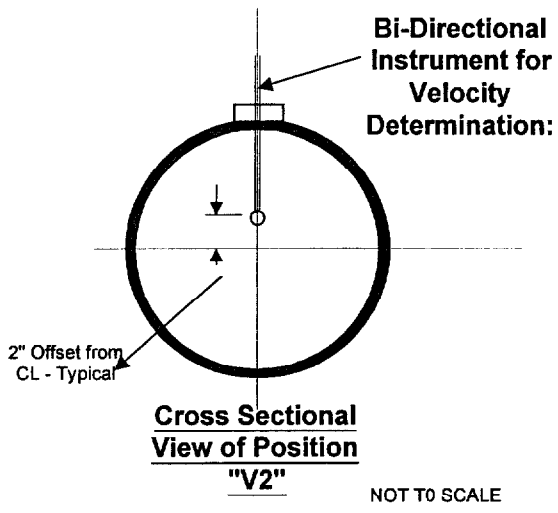
TASK 3: The Task 2 test set-up was also utilized for this task, except that sprinkler position 2 was changed to a piping manifold to permit the sprinkler to discharge water when operated. A pressure transducer and flow meter were incorporated

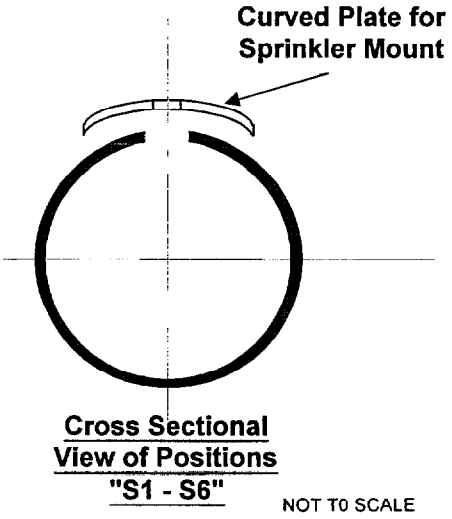
into the piping manifold. Sprinkler position 4 was fitted with an automatic sprinkler.

The tasks are further described herein.

Figure 1 - General Set-Up







SPECIFIC TEST CONDITIONS:

TASK 1 - DETERMINE DIFFERENCES IN THE OPERATING TIMES AND APPARENT RESPONSE TIME INDEX (RTI) OF LISTED SPRINKLERS HAVING FUSIBLE LINK OR GLASS BULB HEAT RESPONSIVE ELEMENTS USING A SPRINKLER SENSITIVITY PLUNGE OVEN.

Ten test sets were conducted to evaluate the difference in operating times and calculated apparent Response Time Index (RTI) between fusible link and glass bulb element sprinklers.

TEST SET-UP / SAMPLES:

Ten sets of ten (10) uncoated sprinklers in the ordinary temperature range were subjected to the plunge oven sensitivity test described in UL199. The sprinkler types are described in Table 1. The orientation of the sprinklers in the plunge oven had the frame arms parallel and perpendicular to the air stream for evaluation of relative response times.

Table 1 - Task 1 Sprinkler Attributes

Test No.	Sprinkler Designation	Temp. Rating, °F	Element Type	Frame Arm Orientation	Element Location
1	A	165	Link	Parallel	Link Parallel to Air Flow
2	A	165	Link	Perpendicular	Link Facing Upstream
3	A	165	Link	Perpendicular	Link Facing Downstream
4	B	165	Link	Parallel	Link Parallel to Air Flow
5	B	165	Link	Perpendicular	Link Facing Upstream
6	B	165	Link	Perpendicular	Link Facing Downstream
7	C	155	Bulb, 5mm	Parallel	N/A
8	C	155	Bulb, 5mm	Perpendicular	N/A
9	D	155	Bulb, 3mm	Parallel	N/A
10	D	155	Bulb, 3mm	Perpendicular	N/A

N/A - Not Applicable

DATA COLLECTION

During the tests, the data collection included the following:

1. Sprinkler operating time.
2. Plunge oven temperature.
3. Plunge oven air velocity.
4. Room ambient temperature.
5. Description and orientation of sprinkler under test.

TEST PROCEDURE:

The tests were conducted in accordance with the methods of UL 199 for the Sensitivity Oven Heat Test.

Sprinkler styles were tested in the sensitivity test oven with the heat responsive elements located at least 1 inch (25.4 mm) away from the inside surfaces of the oven.

For sprinklers A and B, which incorporated fusible link style heat responsive elements, ten samples were orientated in the pendent position with the frame arms in a plane perpendicular to the direction of air flow with the element both upstream and downstream of the air flow. Additionally, ten samples were oriented with the frame arms parallel to the air flow.

For sprinklers C and D, which incorporated glass bulb style heat responsive elements, ten samples were orientated in the pendent position with the frame arms in a plane perpendicular to the direction of air flow, and ten samples were oriented in the pendent position with the frame arms in a plane parallel to the direction of air flow.

The samples were conditioned at 75 ± 2°F (24 ± 1°C) for at least 2 hours. The inlet end of each sprinkler sample was connected to a source of air pressure at 4 ± 1 psig (28 ± 7 kPa) and quickly plunged into the sensitivity test oven in a pendent position. Each sprinkler was observed to determine operation time.

A constant air velocity of 8.33 ± 0.05 feet per second (2.54 ± 0.01 m/s) and an air temperature of 275 °F (135 °C) were established in the test oven. Air velocity was measured using a bi-directional probe and a velometer. The air temperature was measured by use of a No. 30 AWG (0.05 mm) thermocouple centered upstream from the sprinkler.

RESULTS:

Table 2 defines the operation times of the applicable sprinklers and the calculated RTI values:

Table 2 - Task 1 Results

Test No.	Sprinkler Designation	No. of Samples	Frame Arm Orientation	Average Operating time, sec.	Average RTI (ft*sec) ½
1	A	10	Parallel	52.1	253.5
2	A	10	Perpendicular	41.0	199.4
3	A	10	Perpendicular	57.4	279.4
4	B	10	Parallel	16.4	80.0
5	B	10	Perpendicular	10.8	52.8
6	B	10	Perpendicular	12.9	63.0
7	C	10	Parallel	43.4	247.5
8	C	10	Perpendicular	35.5	202.5
9	D	10	Parallel	19.5	111.4
10	D	10	Perpendicular	12.0	68.6

TASK 2 - DETERMINE OPERATION TIMES FOR STANDARD AND QUICK RESPONSE SPRINKLERS HAVING VARIOUS CORROSION PROTECTION METHODS INSIDE A 12 INCH DIAMETER DUCT FLOWING HEATED AIR.

TEST SET-UP / SAMPLES:

Using the information from Task 1 above, it was determined that the designation "A" sprinkler with the heat responsive element downstream and the frame arms perpendicular to the heated air flow would provide the slowest activation time. Since Task 2 required both standard and quick response sprinklers, it was determined that the designation "B" sprinkler would be used for the quick response sprinkler, being that it was almost identical in design to the designation "A" sprinkler, except for the heat responsive element.

Six samples of the above sprinklers which incorporated various corrosion protection methods (described below) were installed in a nominal 1 foot diameter galvanized steel duct on four foot centers (see Fig. 1). Bulkhead style fittings used to mount the sprinklers in the duct. The use of a nominal 1 inch hole drilled into the top of a cut-away section of the duct in

combination with the bulkhead fitting and sprinkler adapter defined the sprinkler's position inside the duct (see Fig. 1). The sprinkler's frame arms were oriented perpendicular to the duct and the fusible heat responsive element was positioned downstream for all the tests described in Table 3.

The test parameters included the response characteristics of the sprinkler and the protection provided to the heat responsive element. A list of the conducted tests are shown in Table 3.

Table 3 - Task 2 Sprinkler Attributes / Corrosion Protection Methods.

Test No.	Response Type	Corrosion Protection Method
1	Standard	None
2	Standard	Factory Wax Coated
3	Standard	Single Plastic Bag Over Uncoated (Heavy and Light)
4	Standard	Factory Wax Coated with Single Bag (Heavy and Light)
5	Standard	Factory Wax Coated with Double Bag (Heavy and Light)
6	Standard	Flexible Hose Product (Double Production Bag with Gasket)*
7	Quick	None
8	Quick	Single Plastic Bag Over Uncoated (Heavy and Light)
9	Quick	Double Plastic Bag Over Uncoated (Heavy and Light)
10	Quick	Double Flexible Hose Product's Plastic Bag with Gasket Over Uncoated

* Note: Two commercially available flexible hose / adjustable drop nipple product assemblies were used for this sensitivity test and were placed in the closest and farthest positions from the duct inlet.

The plastic bagged sprinklers incorporated generic lunch style plastic bags with nylon ties near the sprinkler's wrench flat. The bag was installed loose fitting to the sprinkler (see Figs. 16 and 17, Appendix A). The commercially available flexible hose / adjustable drop nipple product incorporated it's own double plastic bag with gasket assembly which attaches between a set of metal mounting blocks (see Figs. 34, 52 and 54,

Appendix A). The single ply thickness of this plastic bag was 0.0035 inch.

The single ply thickness of the plastic bags used were 0.0005 and 0.0025 inch for the light and heavy lunch style bags respectively.

INSTRUMENTATION:

Thermocouples were installed a nominal 2.5 inches from each of the six sprinklers such that they would not block the heated air flow. The thermocouples were positioned even with the heat responsive element of the sprinkler.

One bi-directional probe was installed 19 feet downstream of the air intake to measure the required air velocity.

Electronic pressure switches were installed in the piping for each of the six sprinklers to determine operation times.

TEST PROCEDURE:

1. Each sprinkler was pressurized to approximately 5 psi with air such that an installed pressure switch indicated pressure was being maintained.

2. The blower was started and the air velocity was adjusted with dampers to an average of 600 feet per minute, measured at the bi-directional probe at the 19 foot distance from the duct inlet.

3. A 1 foot square, 8 inch high steel pan was positioned directly beneath the duct, inside a five sided enclosure. The duct was positioned such that the heptane surface in the pan was 24 inches below the bottom of the duct and centrally positioned with respect to the duct. The pan was filled with 3 inches of water and 4 inches of heptane for tests 1-5 and 7-9. Reduced quantities of heptane were used for tests 6, 10, 11 and 12. The level of the water was increased in these tests to maintain a 24 inch distance from the bottom of the duct to the heptane surface.

4. After a one minute countdown to record ambient starting duct air velocity, the test was started by igniting the heptane in the pan below the duct.

5. The operating time of each sprinkler was then recorded by the data acquisition system.

6. After all the sprinklers had operated, the fire was extinguished manually.

DATA COLLECTION

During the tests, the data collection included the following:

1. The measurement of the temperatures versus time near each sprinkler position.
2. Air velocity versus time.
3. Sprinkler operation times.

In addition, each test was videotaped.

RESULTS:

The sprinkler operating times are presented in Table 4.

In general, the sprinkler at position 1 had it's corrosion protection removed by the heat generated by the pan fire, while the sprinkler at position 6 had it's corrosion protection distorted depending on the length of time exposed to the fire. The duration of fire exposure depended on the time required to activate the final sprinkler. The photographs in Appendix A illustrate the most and least distorted corrosion protection method for each test, as well as the pre-test condition for comparison purposes.

TABLE 4 - TEST RESULTS

TEST NO.	PROTECTION METHOD	ACTIVATION TIMES (min:sec) (sprinkler position no.): 1	2	3	4	5	6
1	NONE	0:37	0:56	1:06	1:06	1:09	1:12
2	WAX	0:45	0:56	1:08	1:06	1:10	1:20
3	SINGLE HEAVY BAG (#1,3 & 5) SINGLE LIGHT BAG (#2,4 & 6)	1:40	2:08	2:48	2:28	3:08	3:06
4	SINGLE HEAVY BAG (#1,3 & 5) SINGLE LIGHT BAG (#2,4 & 6) OVER WAX COATED	1:5	2:19	3:11	3:25	3:05	4:01
5	DOUBLE HEAVY BAG (#1,3 & 5) DOUBLE LIGHT BAG (#2,4 & 6) OVER WAX COATED	1:55	2:56	3:42	3:24	3:40	4:06
6	DOUBLE COMMERICAL PRODUCT BAG OVER WAX COATED	1:51	2:43	3:05	3:01	3:43	4:05
7	NONE	0:10	0:20	0:26	0:26	0:26	0:30
8	SINGLE HEAVY BAG (#1,3 & 5) SINGLE LIGHT BAG (#2,4 & 6)	1:00	1:10	1:26	1:26	1:28	1:52
9	DOUBLE HEAVY BAG (#1,3 & 5) DOUBLE LIGHT BAG (#2,4 & 6)	1:07	1:35	2:03	2:03	2:03	2:23
10	DOUBLE COMMERICAL PRODUCT BAG	1:10	1:44	2:18	2:18	2:24	2:44

The temperatures near the sprinkler locations for the individual tests as well as the velocity versus time graphs are presented in Appendix B.

TASK 3 - DETERMINE THE INFLUENCE OF SPRINKLER WATER DISCHARGE ON THE RATE OF HEATED AIR FLOW THROUGH A DUCT.

Two tests were conducted to investigate sprinkler spray interaction with heated duct air flow.

TEST SET-UP / SAMPLES:

The duct, heptane pan and enclosure arrangement were the same as from task 2, except that the heptane pan was moved away from the duct inlet to prevent the sprinkler discharge from filling the heptane pan after operation. A half duct section was installed such that it acted as a hood to collect the heat of the heptane pan fire, and channel it into the duct.

The heptane pan was moved back so that the closest edge of the pan was 20 in. away from the main duct's inlet. The pan was raised up on cinder blocks 7.5 in. off the ground so that the sprinkler discharge would flow around the cinder block and not effect the heptane fire in the pan.

The six sprinkler positions from task 2 were replaced with an automatic sprinkler (designation "A") flowing water at position number 2, and an automatic sprinkler (designation "A") pressurized with air only at position number 4 (see Fig. 1). Both sprinklers incorporated a double heavy plastic bag (as defined in task number 2).

The sprinkler and water connection assembly incorporated a fixed length of pipe connected to a tee, with the sprinkler attached inside the duct at sprinkler position 2. Tests were conducted with the sprinkler frame arms positioned perpendicular and parallel to the duct.

INSTRUMENTATION:

The instrumentation was identical to that employed in Task 2 with the addition of a water flowmeter and a pressure transducer to establish the flowrate of the sprinkler at position 2.

TEST PROCEDURE:

The duct velocity 19 feet from the inlet was stabilized at a nominal 600 feet per minute using methods established in Task 2. The sprinkler at position 2 was connected to a water supply and pressurized with water in order to establish specific flowrates after activation.

After the sprinkler operated, water flow was adjusted to 30 gpm and the instrumentation continued to record for an additional 1 to 2 minutes to determine the effects of the sprinklers discharge on the recorded parameters. The flowrate was then increased to 45 gpm for a similar time frame.

DATA COLLECTION

The data collection was identical to that described in Task 2 except that the flow rate and flowing pressure of the sprinkler were also recorded.

RESULTS:

The automatic sprinkler at position 2, operated at 6 minutes and 6 minutes, 21 seconds for the test number 11 and 12 respectively. The sprinkler in position number 4 did not operate in either test.

For the sprinkler at position 2, the double heavy plastic bag was distorted and did not adhere to the sprinkler's deflector or most of the frame arms, such that the discharge pattern potentially was not effected by the corrosion protection method employed. For the sprinkler at position 4, the double plastic bag totally encased the sprinkler and hardened due to the sprinkler discharge.

The measured air velocities for the flowing sprinkler tests are shown in the Table 5:

TABLE 5 - VELOCITY SUMMARY FOR TASK 3 HYDRAULIC TESTS

TEST NO.	SPRINKLER DESIGNATION	RESPONSE	FLOWING SPRINKLER ORIENTATION	AVERAGE VELOCITY, 19 ft. DOWNSTREAM OF DUCT INLET, (ft./min.) VELOCITY AT 0 GPM	VELOCITY AT 30 GPM	VELOCITY AT 45 GPM
11	A	SR	Frame arms perpendicular to duct	592	502	481
12	A	SR	Frame arms parallel to duct	588	542	496

S U M M A R Y

This Report provides test data which was obtained under a Special Services Investigation of operation times for duct mounted, corrosion protected sprinklers and the influence of sprinkler spray on heated air flow through ducting. This investigation was conducted for HSB Industrial Risk Insurers concerning the delay in response time for different protection methods, and the effects of sprinkler discharge on the rate of air flow through the duct.

The results are to be used by HSB Industrial Risk Insurers in establishing duct protection criteria for corrosive environments.

This terminates our work under Project 97NK29176, File NC1838.

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APPENDIX A

Duct Mounted, Corrosion Protected Sprinkler

Test Photographs

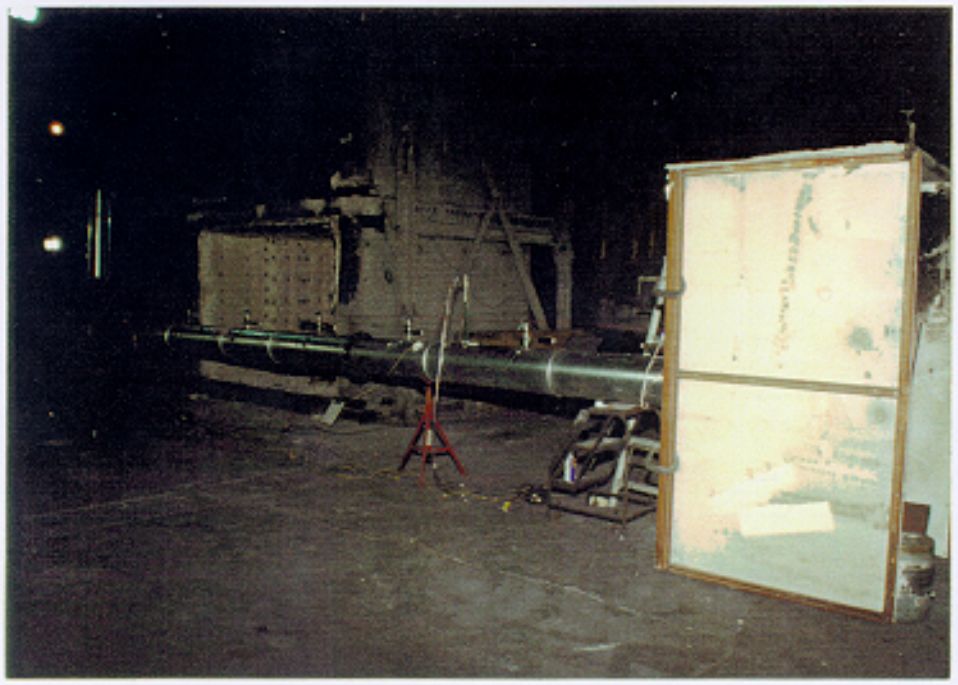


Figure 1 – Task 2 and 3: Test set-up showing Enclosure to the Right and duct.

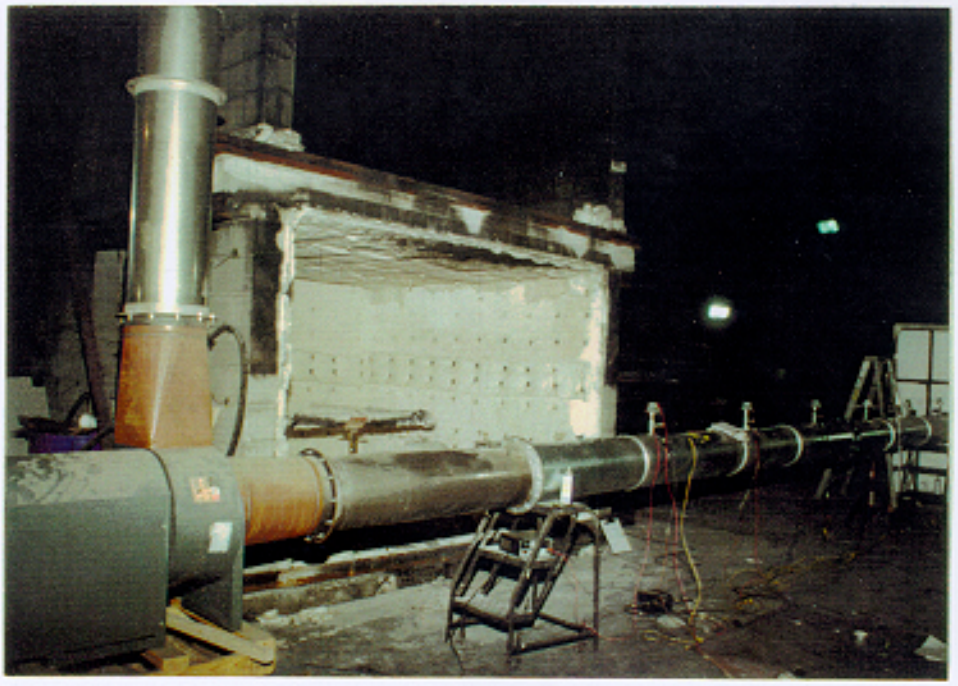


Figure 2 – Task 2 and 3: Test set-up showing Blower assembly to the Left, duct and enclosure to Extreme right.

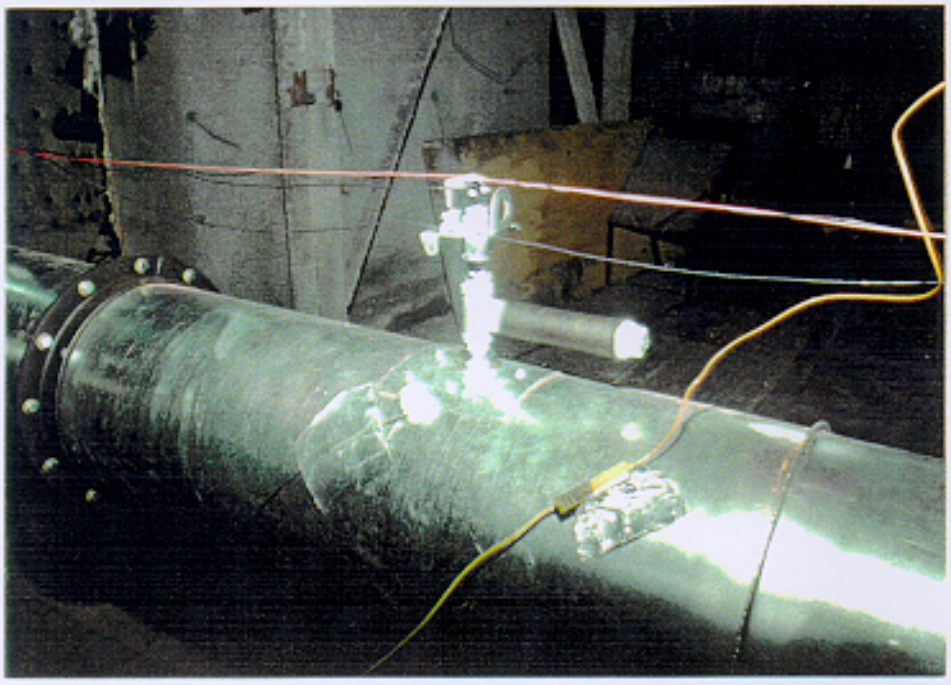


Figure 3 – Task 2:
Test set-up showing Pressure switch Assembly for Sprinkler at position No.6.

Figure 4 – Task 2:
Test set-up showing Heptane pan location With respect to duct inlet.

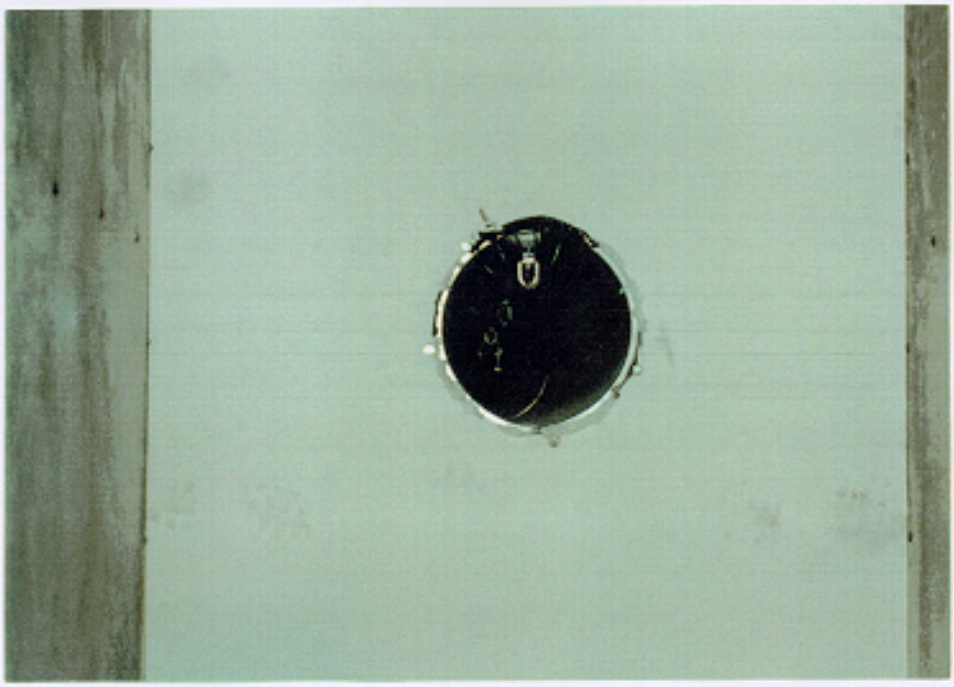


Figure 5 – Task 2:
Test #1 pre-test showing sprinklers inside duct (positions 1-4 can be seen).

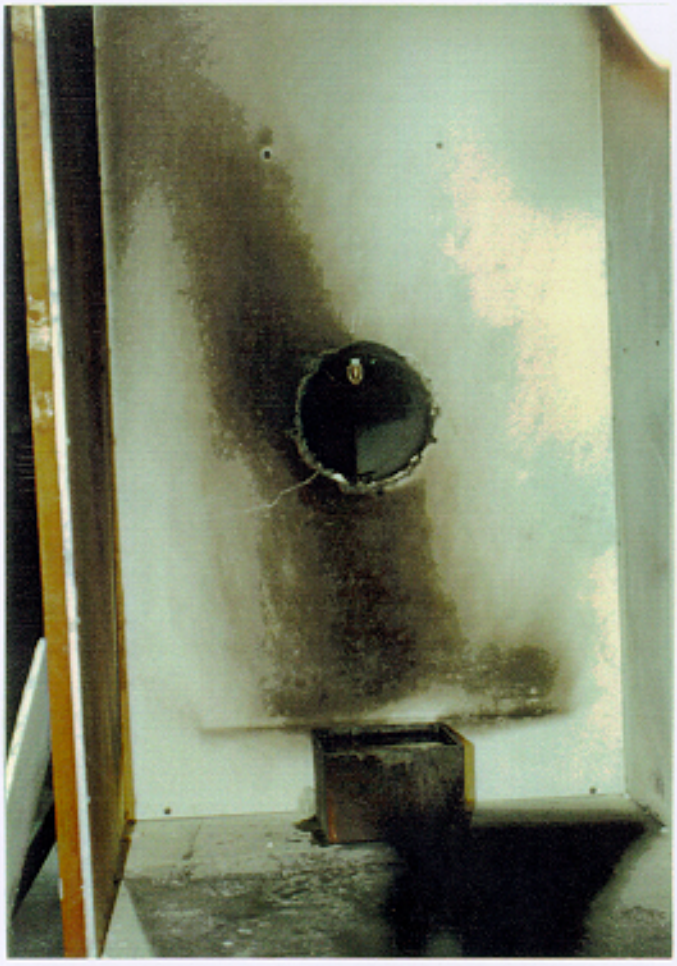


Figure 6 – Task 2:
Test #2 pre-test. scorch marks on drywall from test #1 can be seen.

Figure 7 – Task 2:
Test #1 initial fire growth.

Figure 8 – Task 2:
Test #1 fire developed.

Figure 9 – Task 2:
Test #1 sprinkler prior to test.

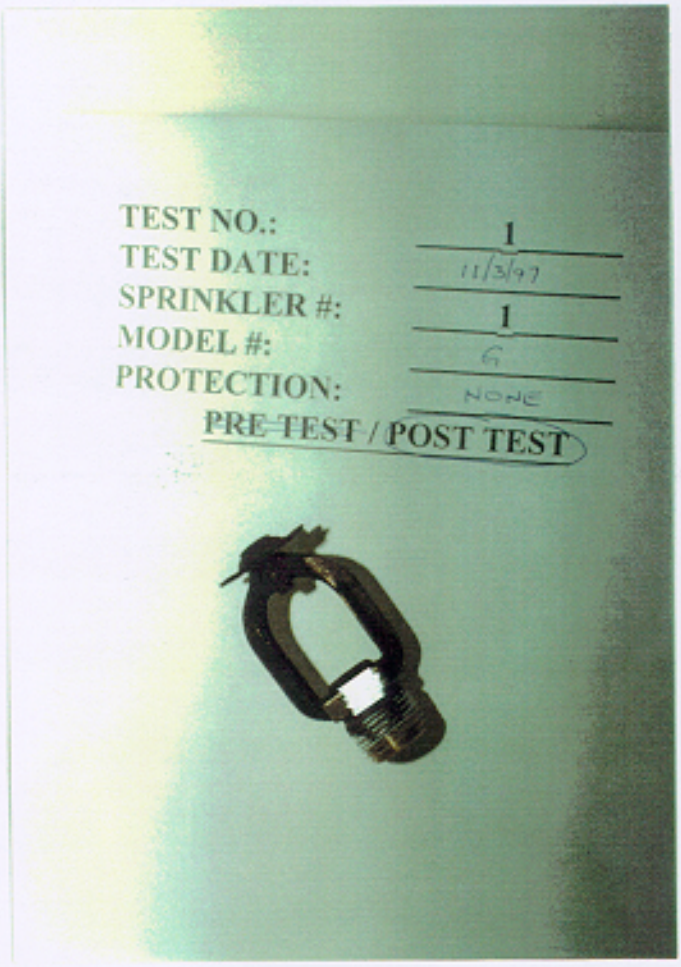


Figure 10 – Task 2:
Test #1 sprinkler position #1, post test.

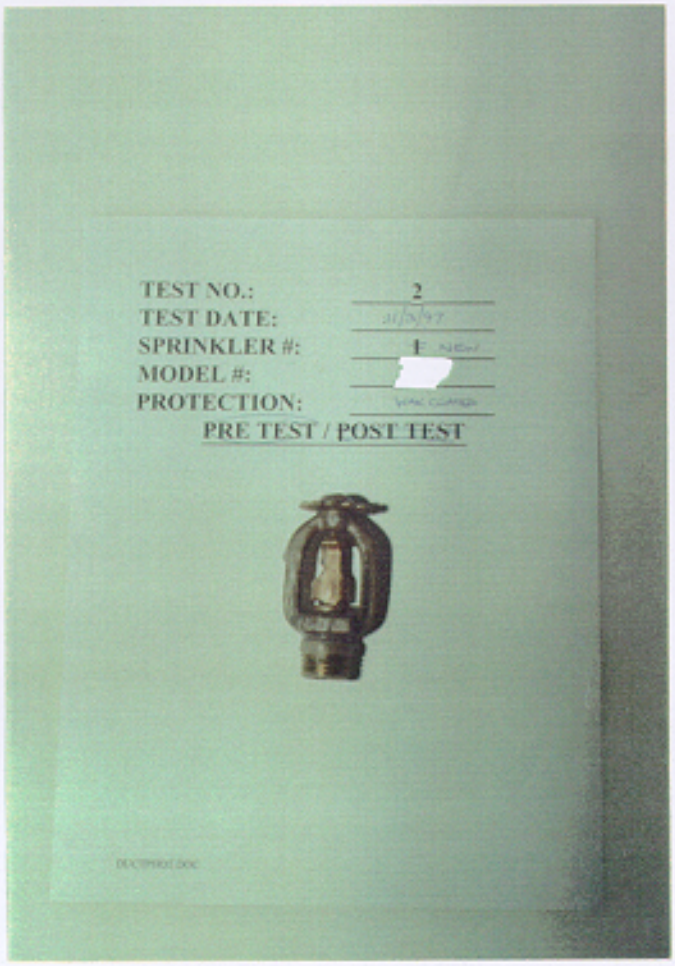


Figure 11 – Task 2:
Test #2 wax coated sprinkler prior to test.

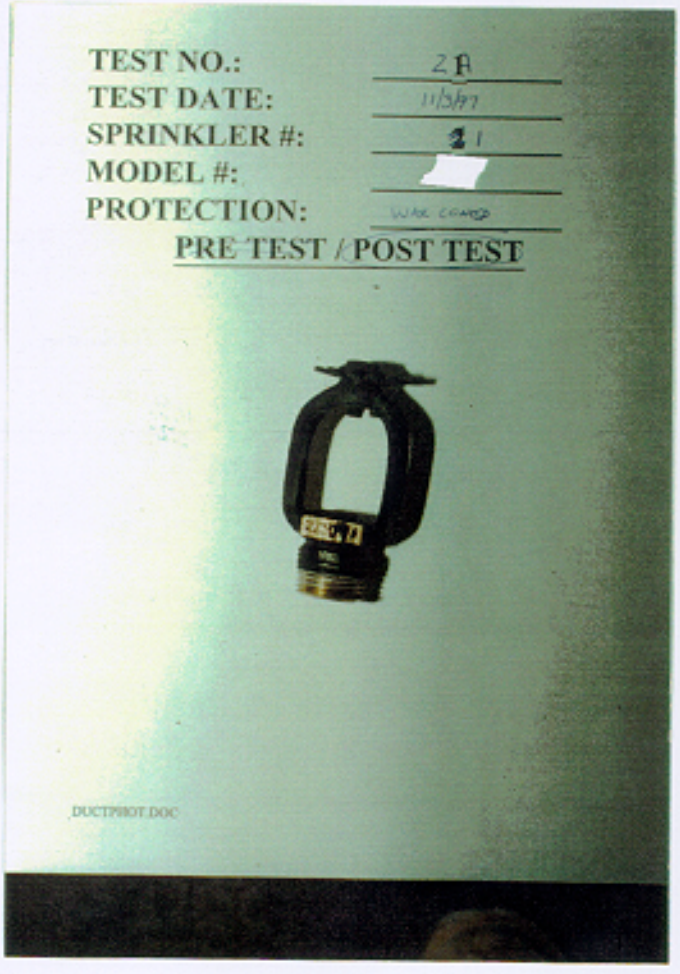


Figure 12 – Task 2:
Test #2 sprinkler position #1, post test.

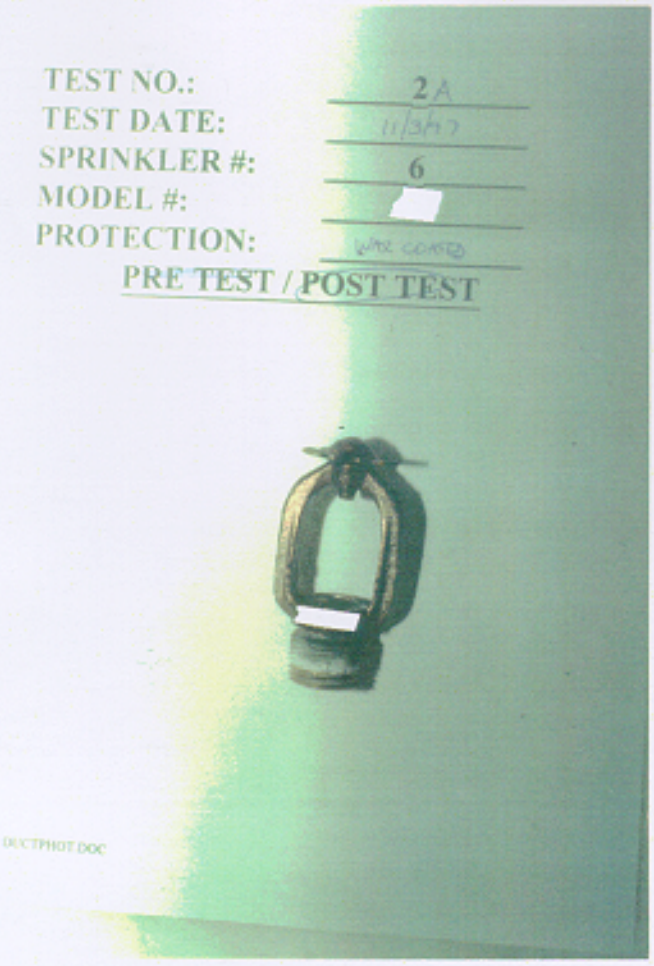


Figure 13 – Task 2:
Test #2 sprinkler position #6, post test.

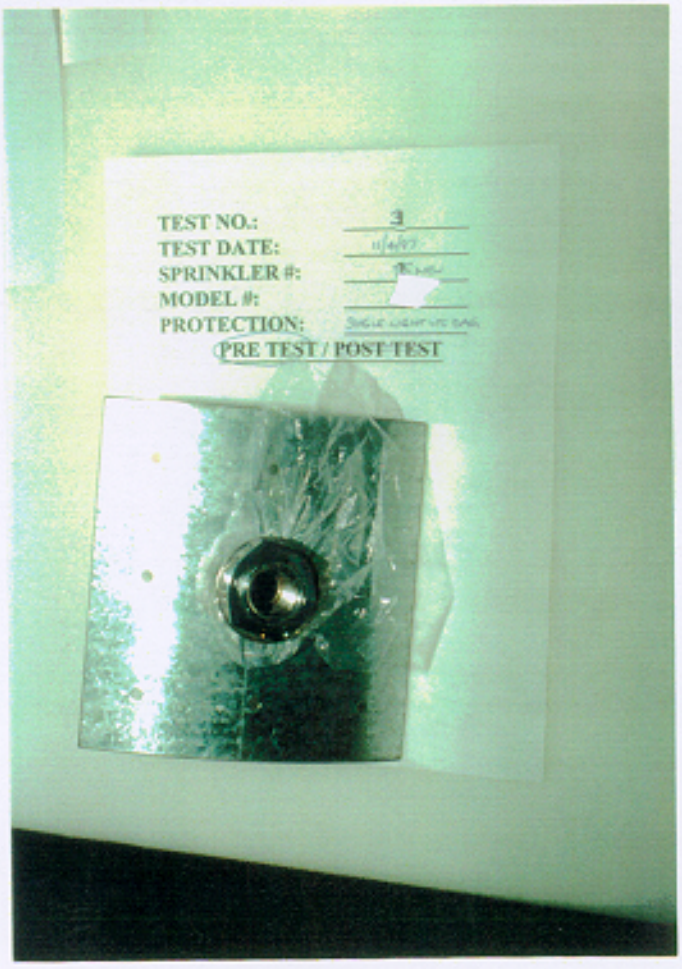


Figure 14 – Task 2:
Test #3 – Representative sprinkler assembly for positions 2, 4 and 6 (light bag through bulkhead from top of assembly).

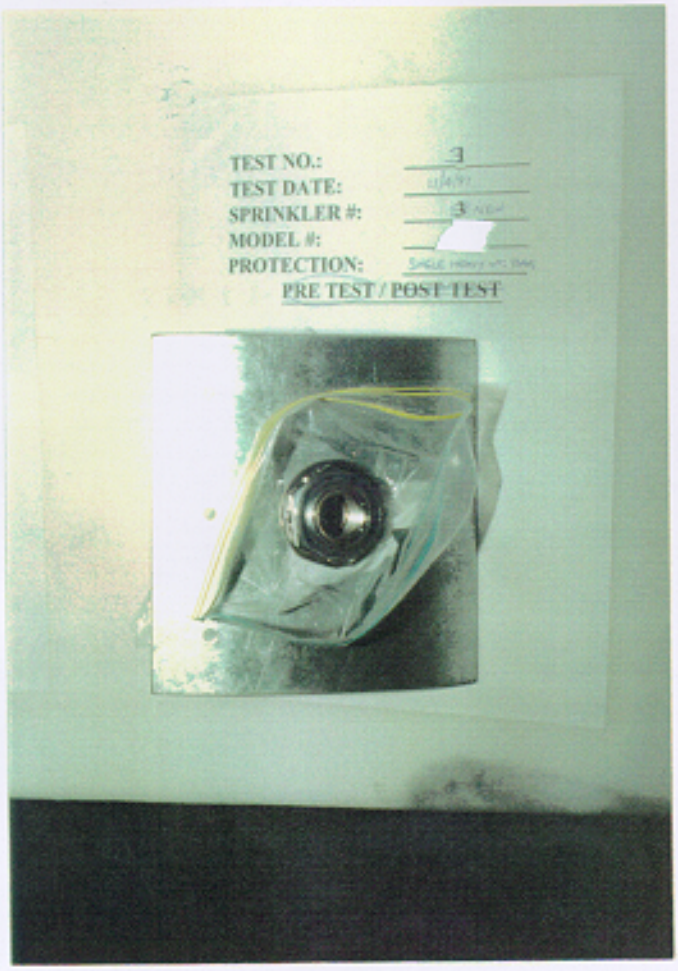


Figure 15 – Task 2:
Test #3 – Representative sprinkler assembly for position 1, 3 and5 (heavy bag through bulkhead fitting from top of assembly).

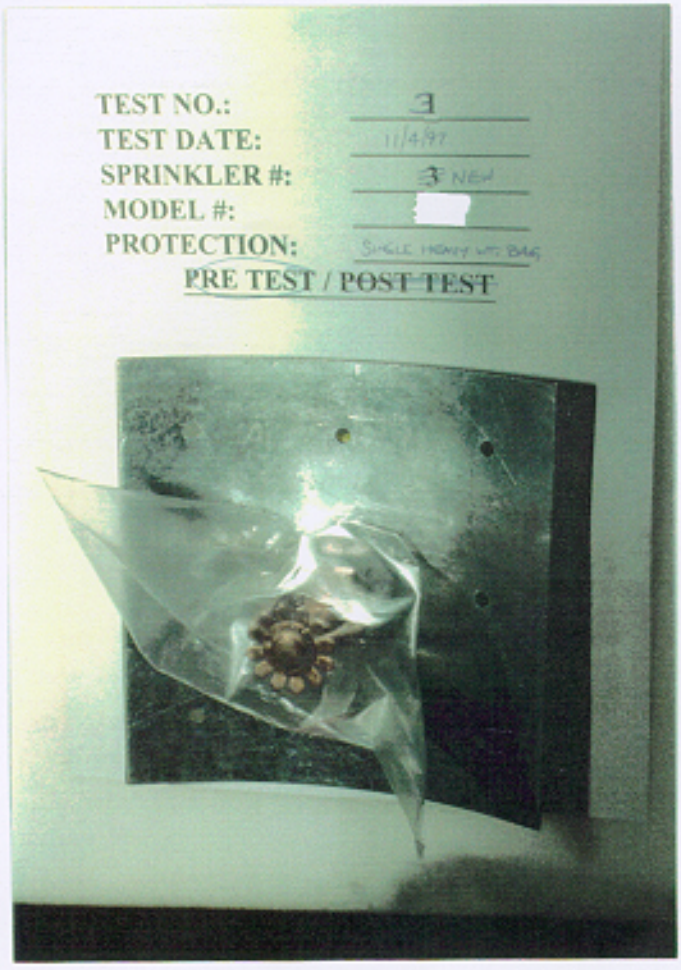


Figure 16 – Task 2:
Test #3 – Representative sprinkler assembly for positions 1, 3 and 5 (heavy bag loosely fitted around uncoated sprinkler).

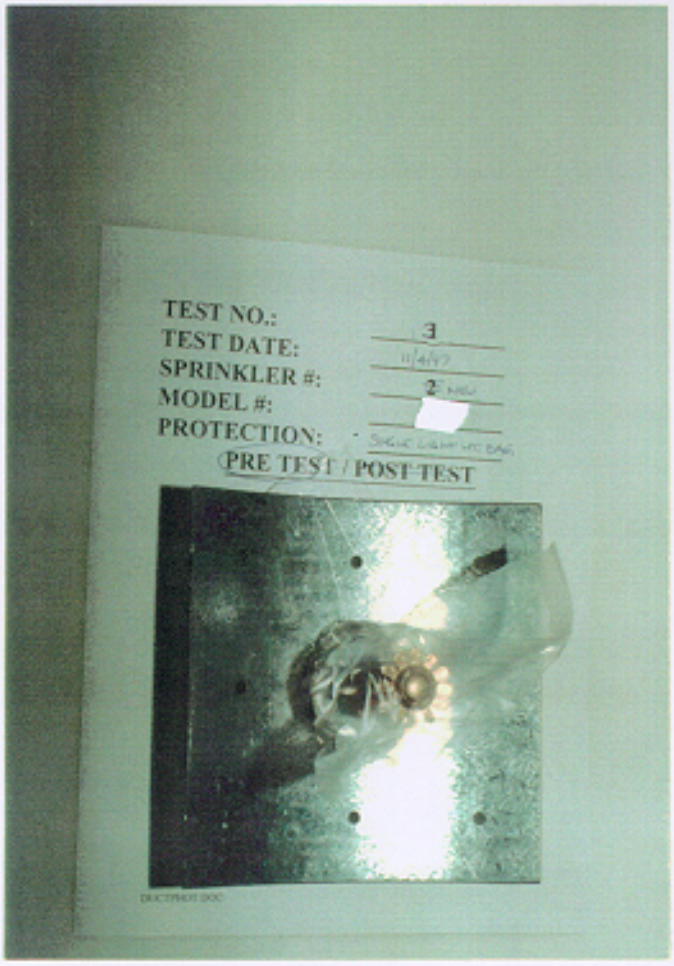


Figure 17 – Task 2:
Test #3 – Representative sprinkler assembly for positions 2, 4 and 6 (light bag loosely fitted around uncoated sprinkler).

Figure 18 – Task 2:
Test #3. Pretest showing sprinkler at position #1 with heavy plastic bag.

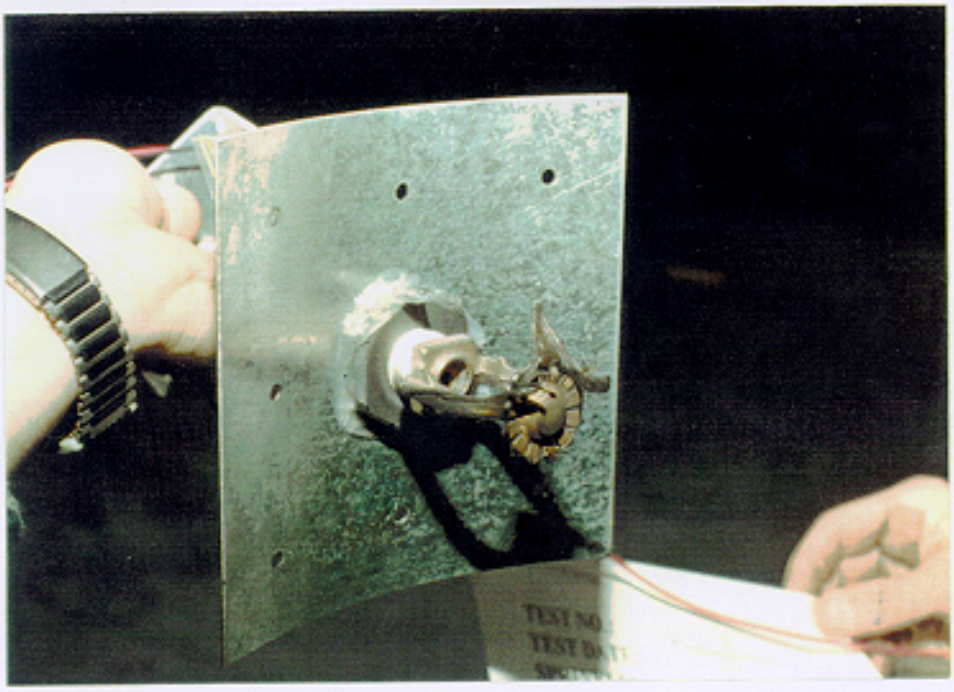


Figure 19 – Task 2:
Test #3, Post test of sprinkler at position #3 (heavy bag). The link and lever were retained by the plastic.

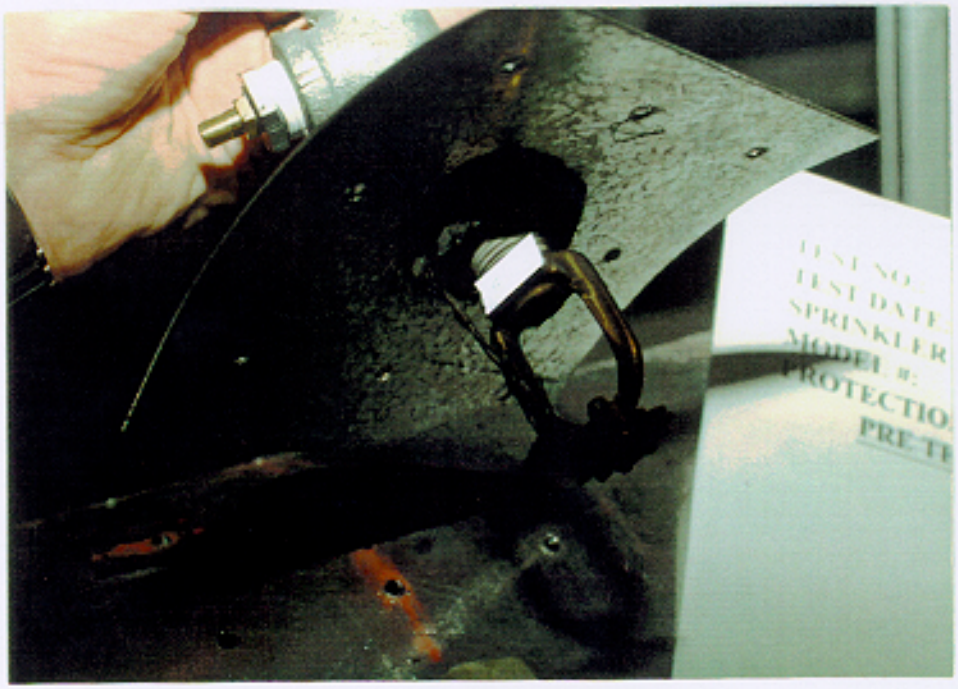


Figure 20 – Task 2:
Test #3, post test of sprinkler at position #2 (light bag). No parts were retained.

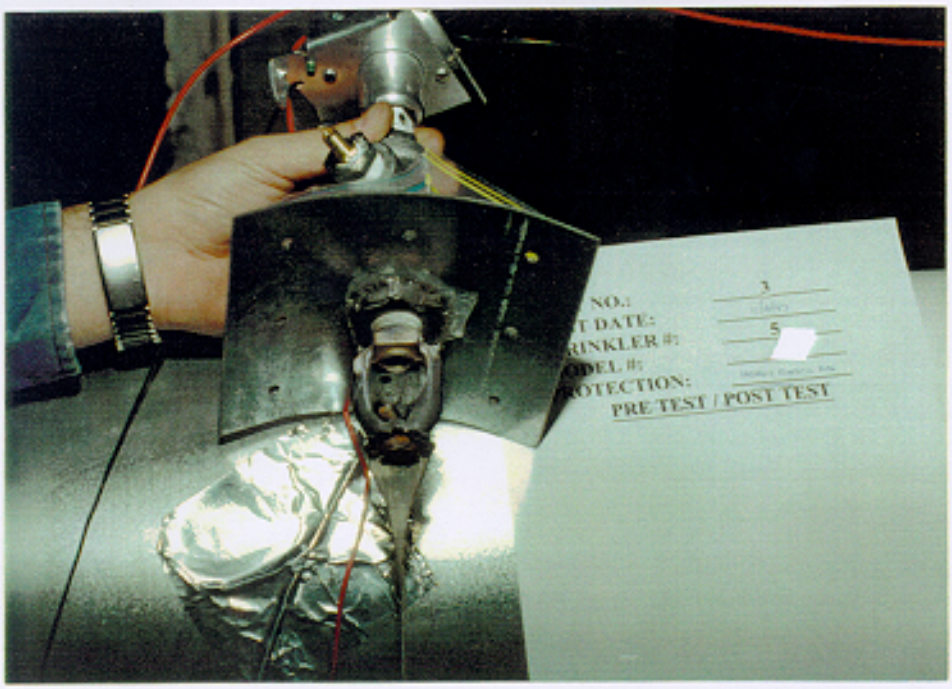


Figure 21 – Task 2: Test #3, post test of sprinkler at position #5 (heavy bag). Plastic extending ~5 in. below deflector. Linkage retained by plastic.

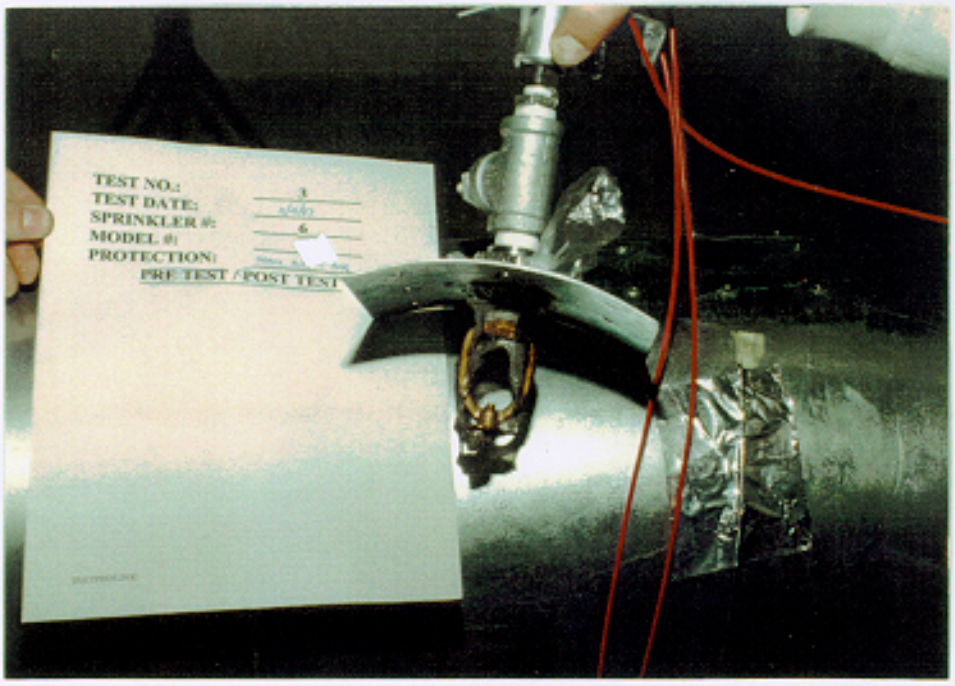


Figure 22 – Task 2: Test #3, Post test of sprinkler at position #6, (light bag). Plastic coated most of sprinkler, no parts were retained.

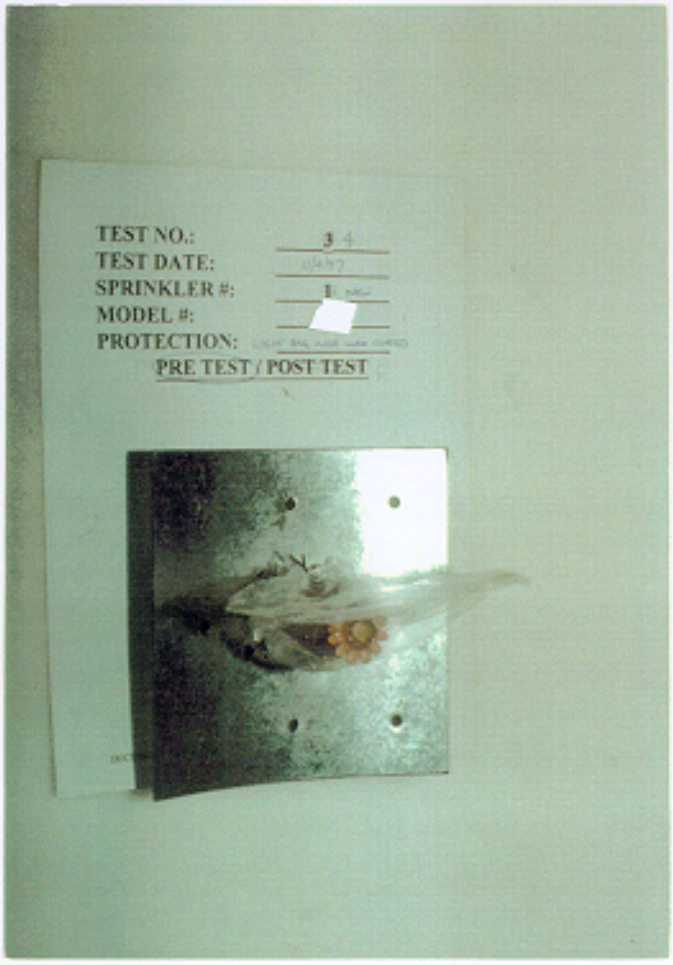


Figure 23 – Task 2:
Test #4, Pre-test showing light bag over wax coated sprinkler (positions 2, 4 and 6). Note the plastic was terminated inside the bulkhead plate with a wire tie.

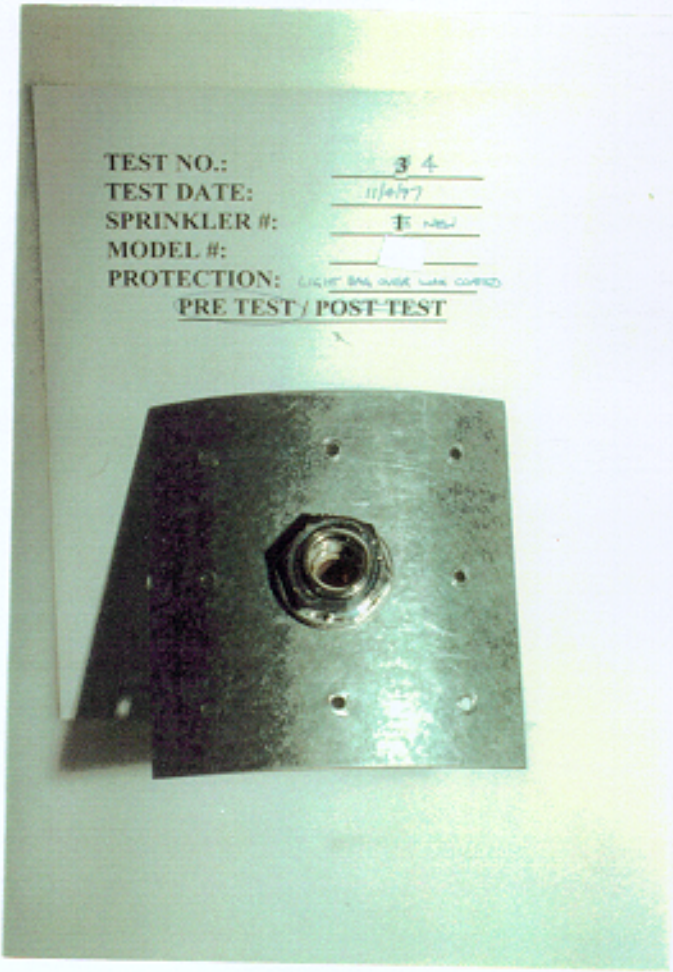


Figure 24 – Task 2:
Test #4, Pre test showing duct / bulkhead fitting assembly without bag on "outside" (as in test #3).

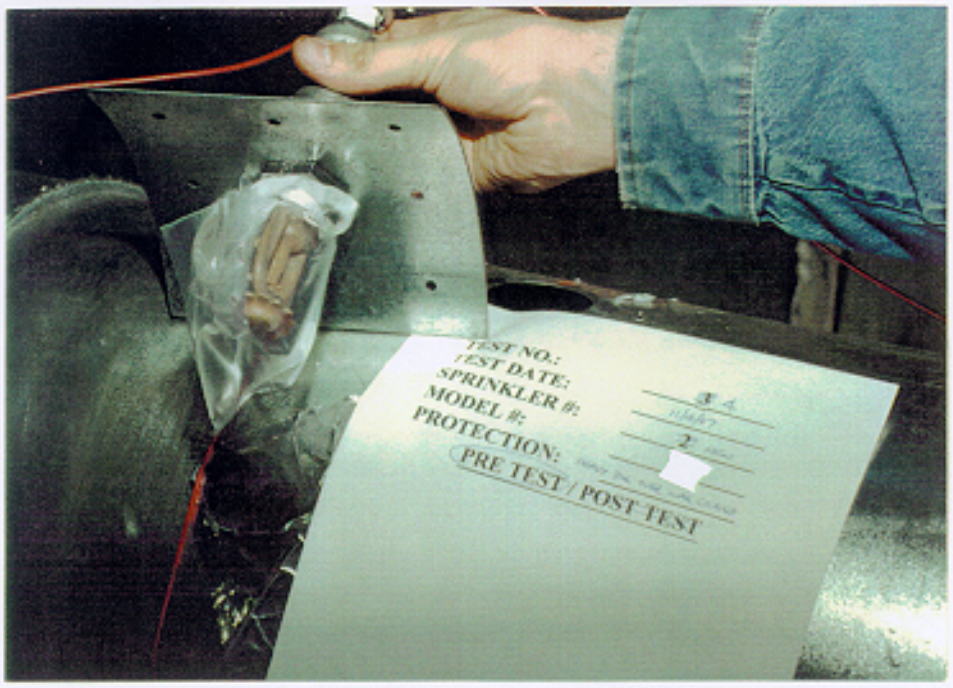


Figure 25 – Task 2:
Test #4, showing representative sample of single heavy bag over wax coated sprinkler prior to installation inside duct.

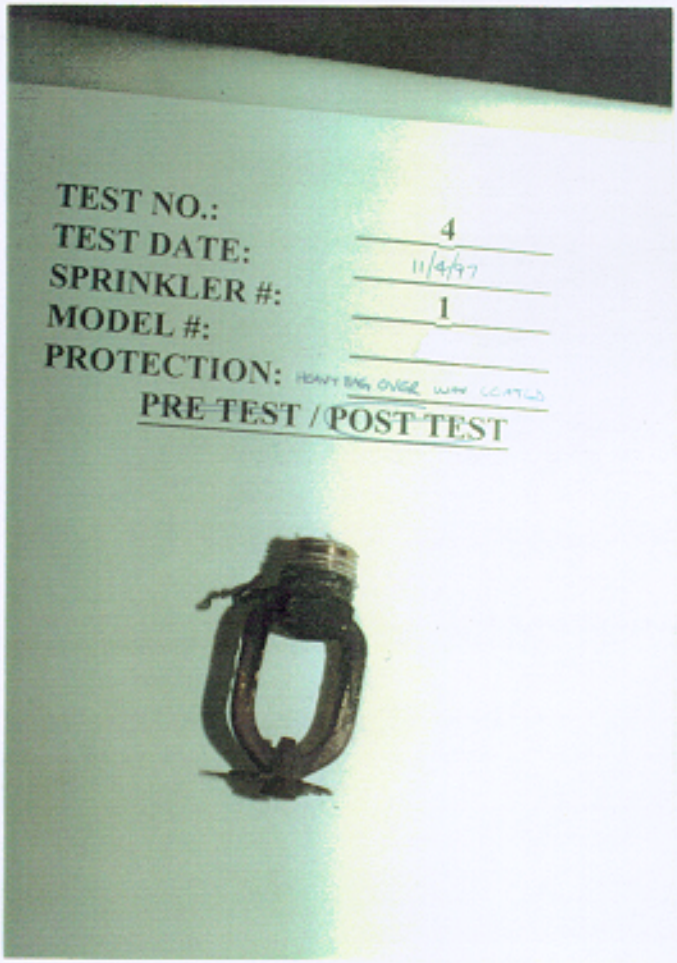


Figure 26 – Task 2:
Test #4, Post test of sprinkler at position #1, (heavy bag).

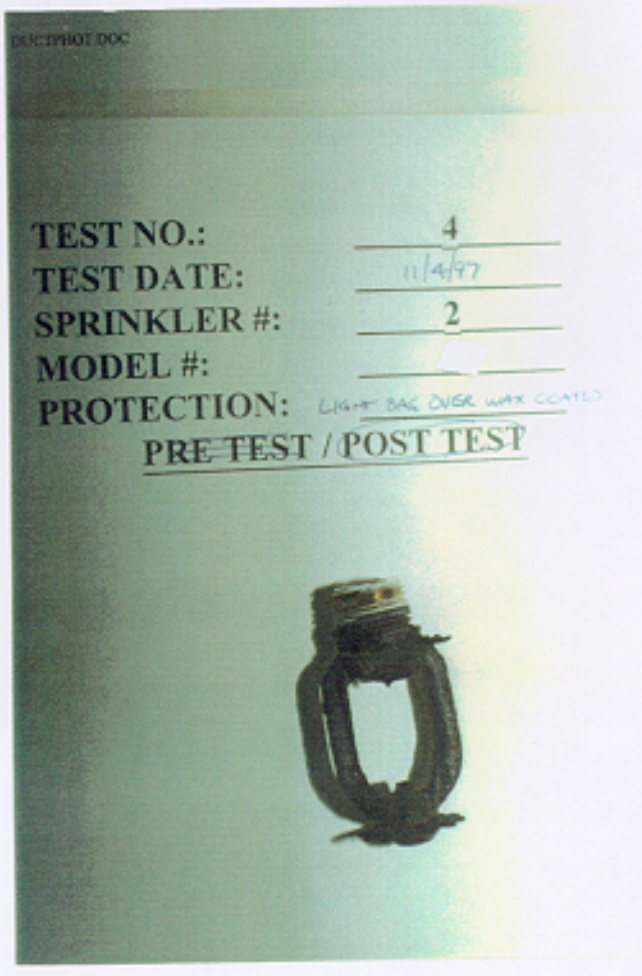


Figure 27 – Task 2:
Test #4, post test of sprinkler at position #2 (light bag). No parts were retained.

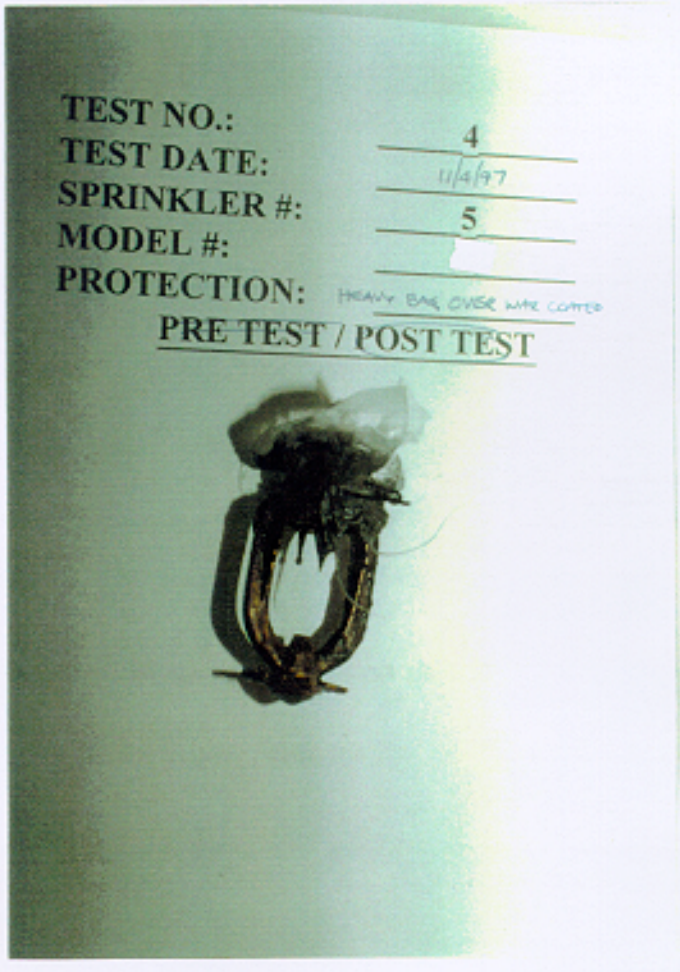


Figure 28 – Task 2:
Test #4, Post test of sprinkler at position #5, (heavy bag). No parts were retained.

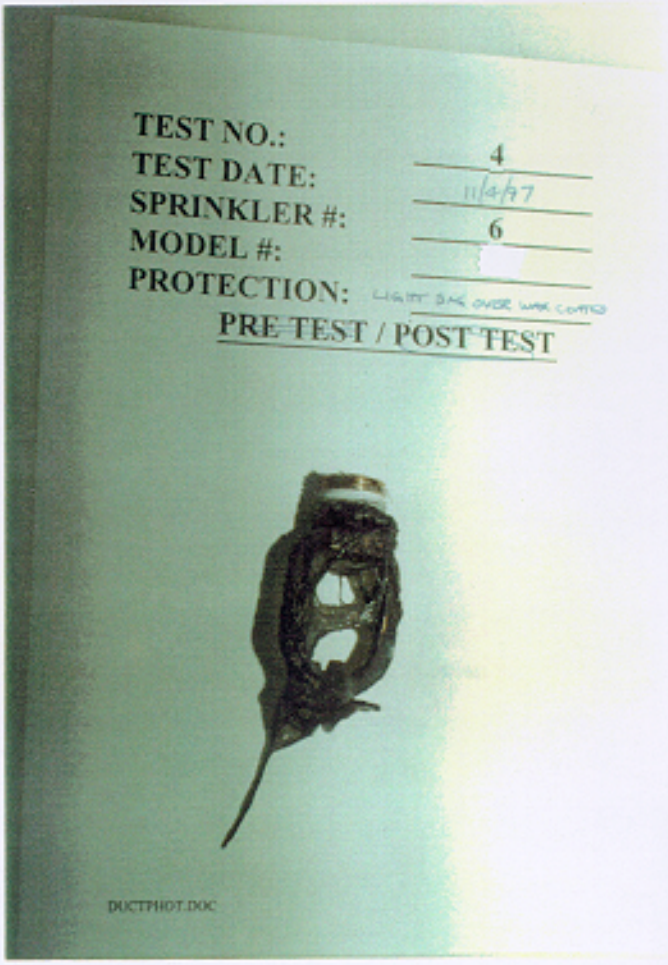


Figure 29 – Task 2:
Test #4, post test of sprinkler at position #6 (light bag), showing plastic coating most of sprinkler.

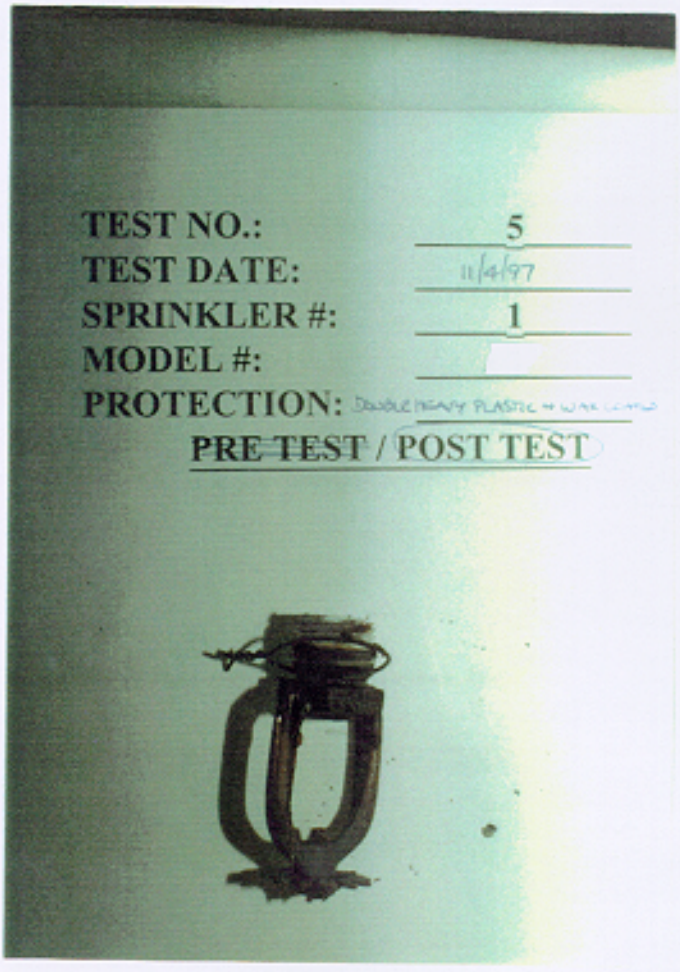


Figure 30 – Task 2:
Test #5, Post test showing sprinkler at position #1.

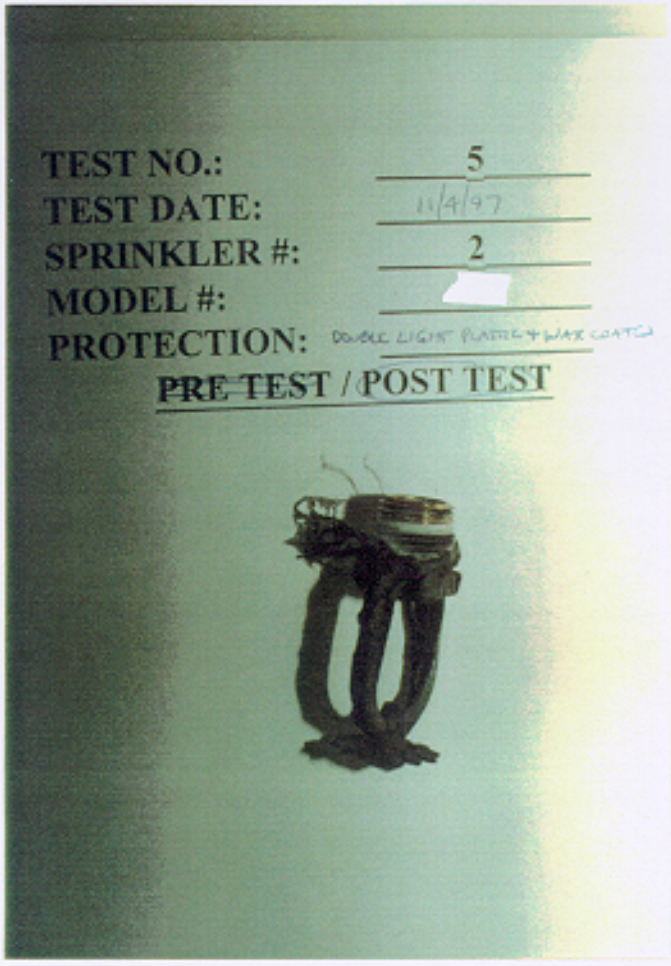


Figure 31 – Task 2:
Test #5, post test of sprinkler at position #2 showing plastic coating most of sprinkler. No parts were retained.

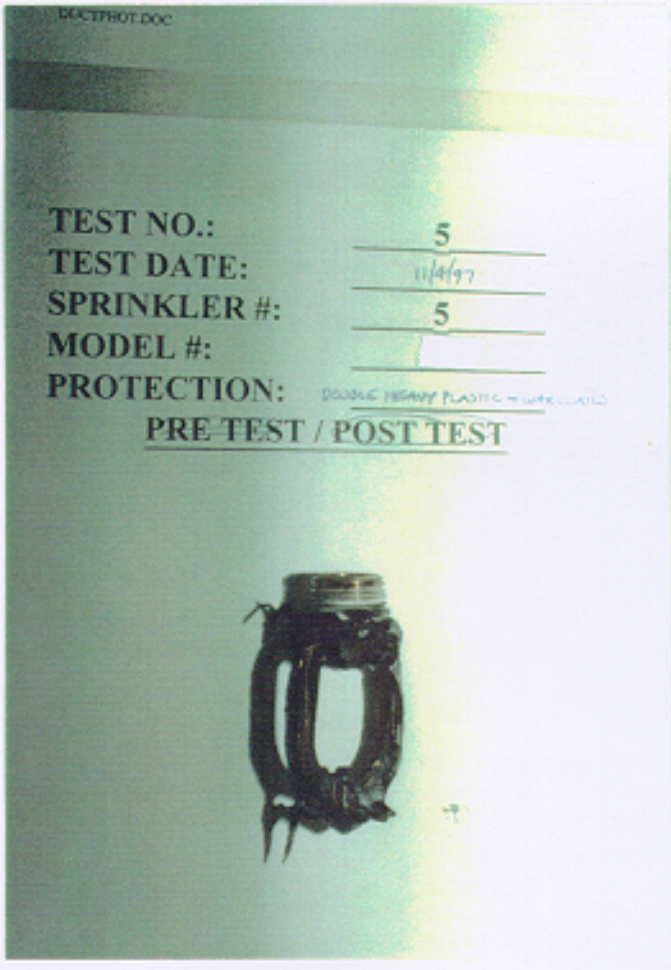


Figure 32 – Task 2:
Test #5, Post test of sprinkler at position #5, (heavy bag), showing plastic coating most of sprinkler. No parts were retained.

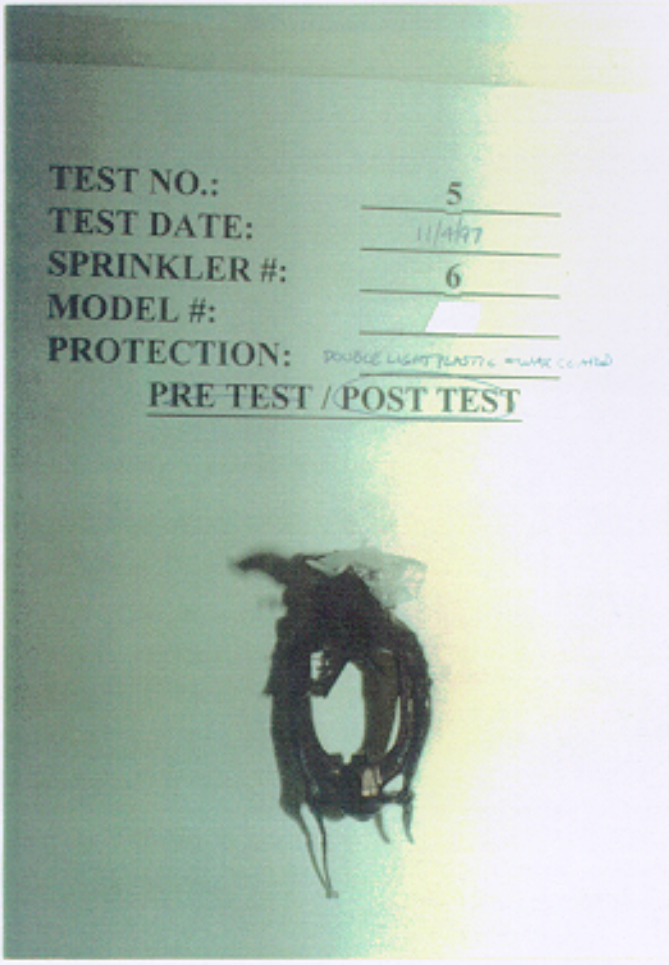


Figure 33 – Task 2: Test #5, post test of sprinkler at position #6 (light bag), showing plastic coating most of sprinkler. No parts were retained.

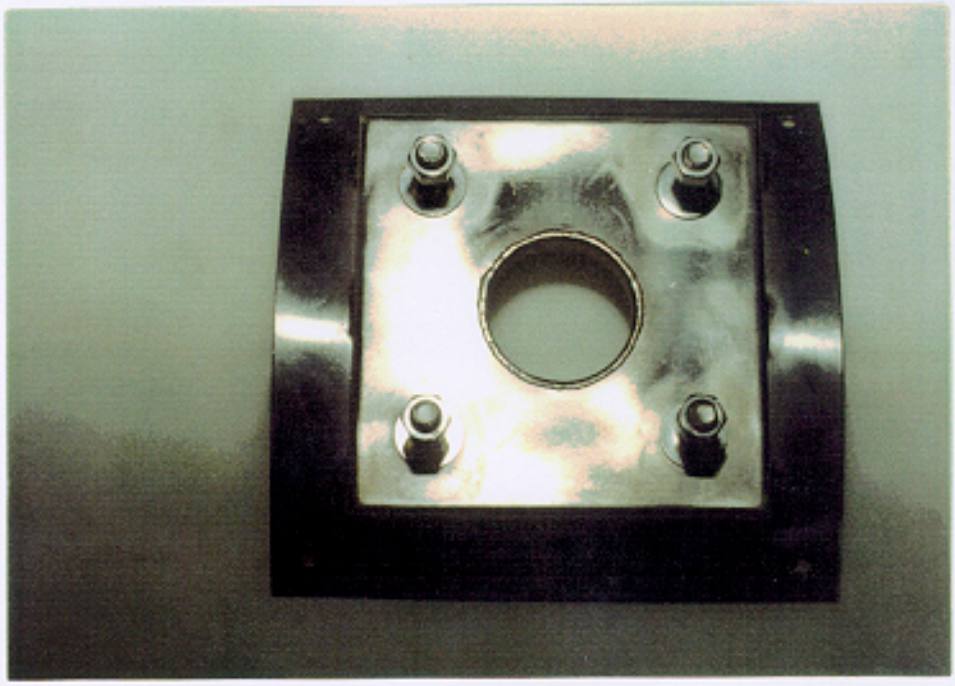


Figure 34 – Task 2: Test #6, Showing commercially available flexible hose assembly's bulkhead mounting plate assembly with gasket material for bag extending over the sides.

Figure 35 – Task 2:
Test #6 / #10, Pre - test showing double plastic bag / gasket assembly (folded).

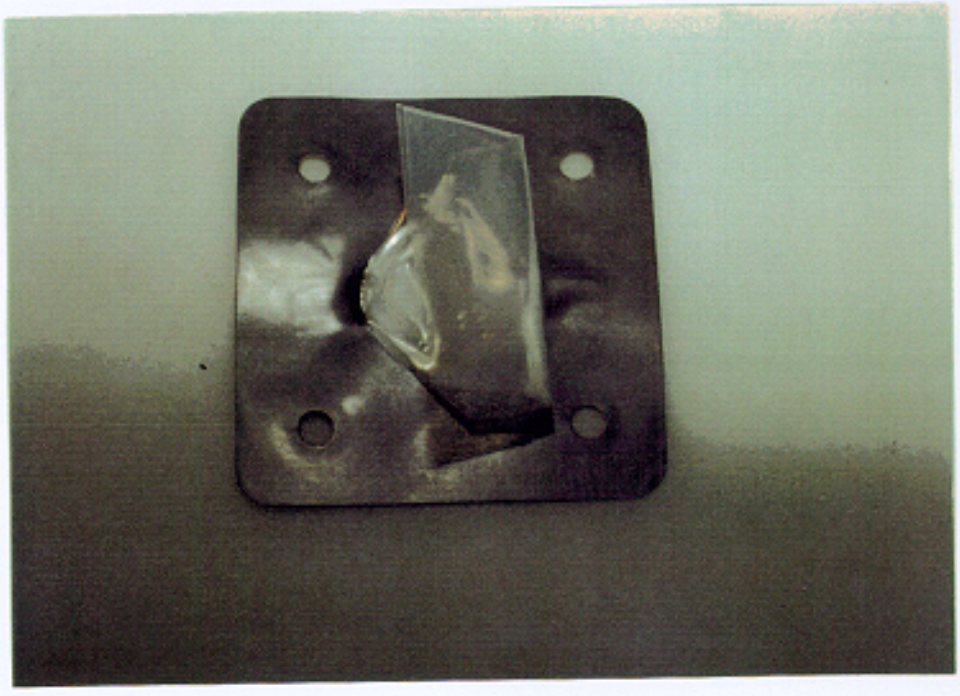


Figure 36 – Task 2:
Test #6 / #10, Pre-test showing double plastic bag / gasket assembly from sprinkler side.

Figure 37 – Task 2:
Test #6 / #10, Pre – test showing double bag / gasket assembly from side with bags unfolded.

Figure 38 – Task 2:
Test #6, Post test of sprinkler at position #1, with most of the plastic removed by heat. The gasket and the sprinkler were separated.

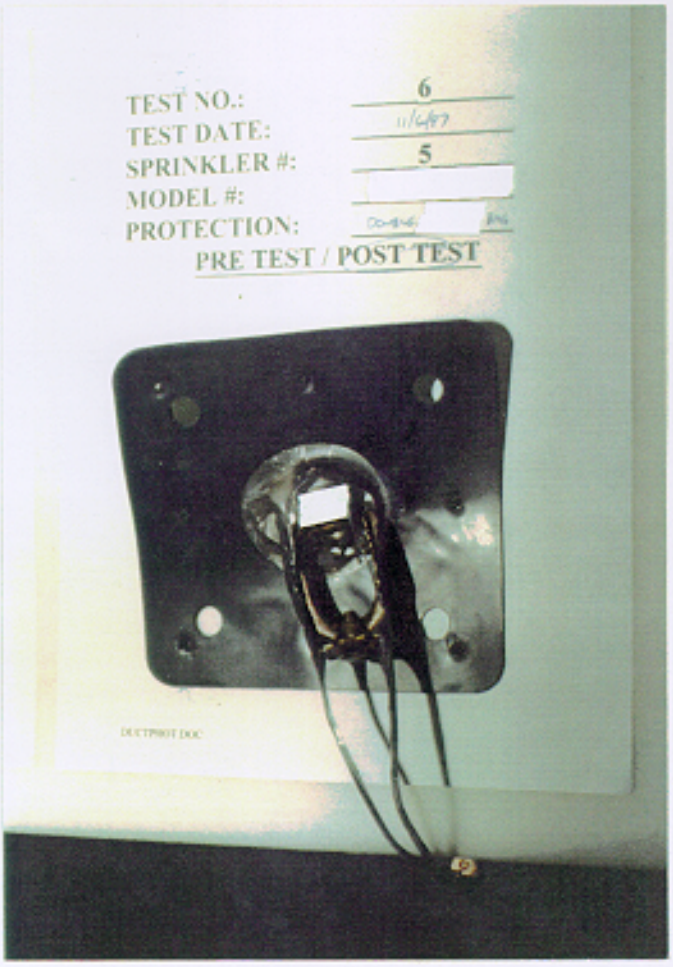


Figure 39 – Task 2:
Test #6, post test of sprinkler at position #5. Gasket assembly retained sprinkler and the plastic retained the link and lever.

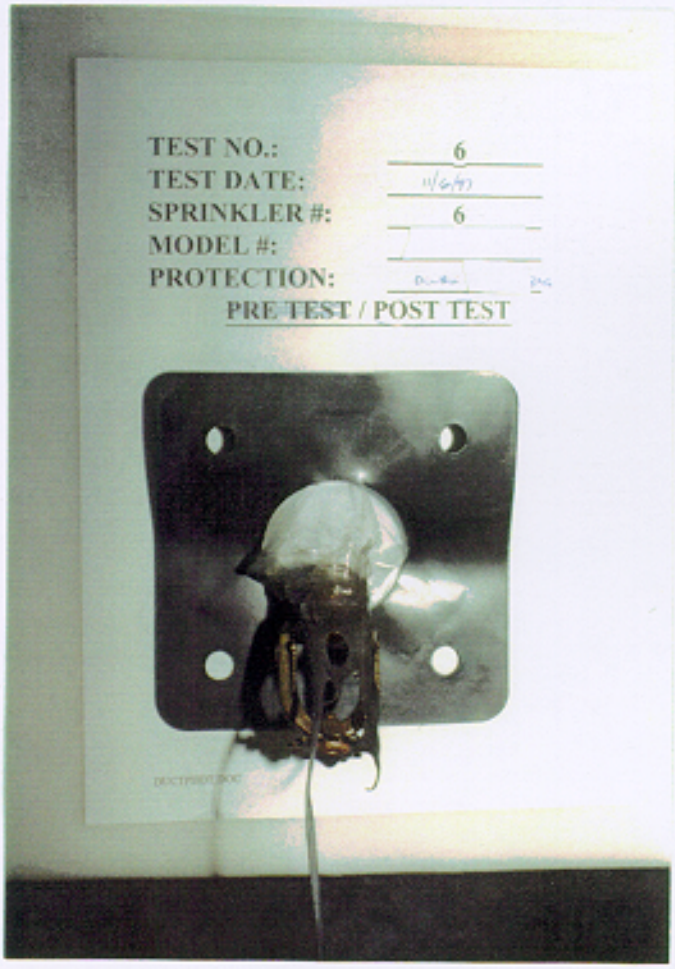


Figure 40 – Task 2:
Test #6, Post test of sprinkler at position #6. Gasket assembly retained sprinkler, however no parts were retained.

Figure 41 – Task 2:
Test #7, post test of sprinkler at position #1.

Figure 42 – Task 2:
Test #8, Pre - test showing single light bag over uncoated quick response sprinkler.

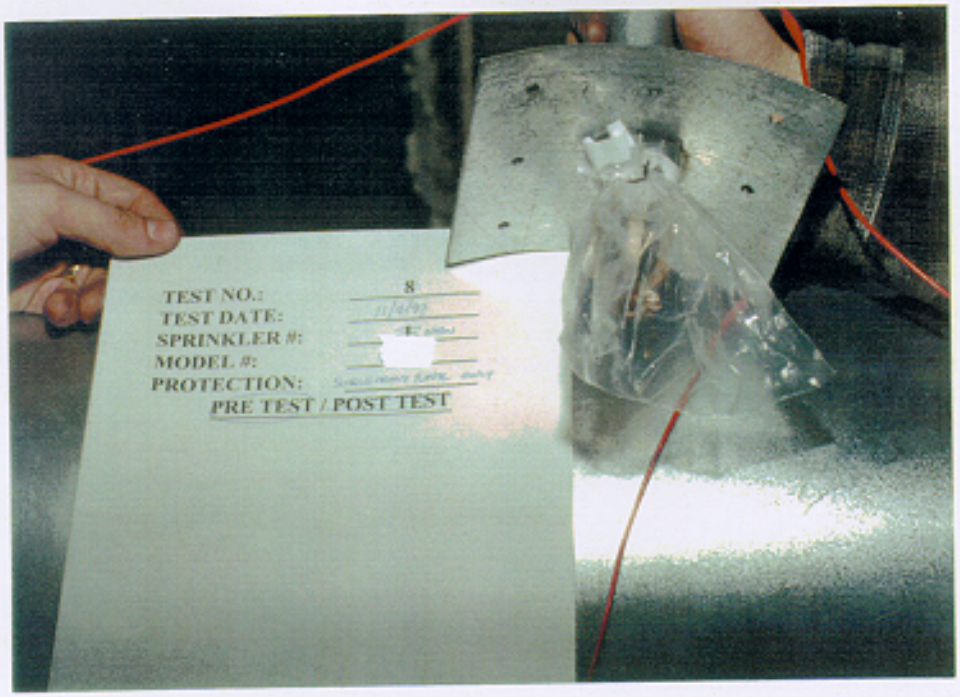


Figure 43 – Task 2:
Test #8, Pre-test showing single heavy bag over uncoated quick response sprinkler.

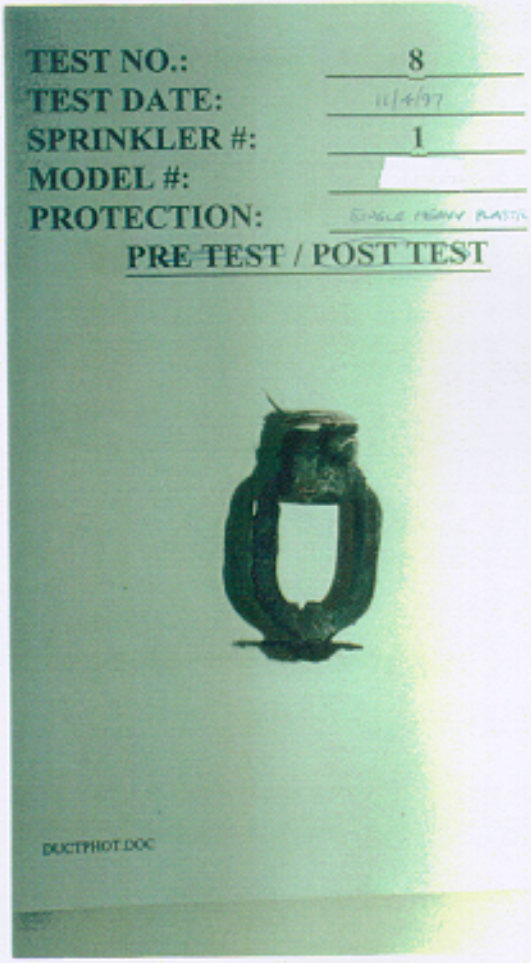


Figure 44 – Task 2:
Test #8, Post - test of sprinkler at position 1 showing light plastic coating over sprinkler with no parts retained.

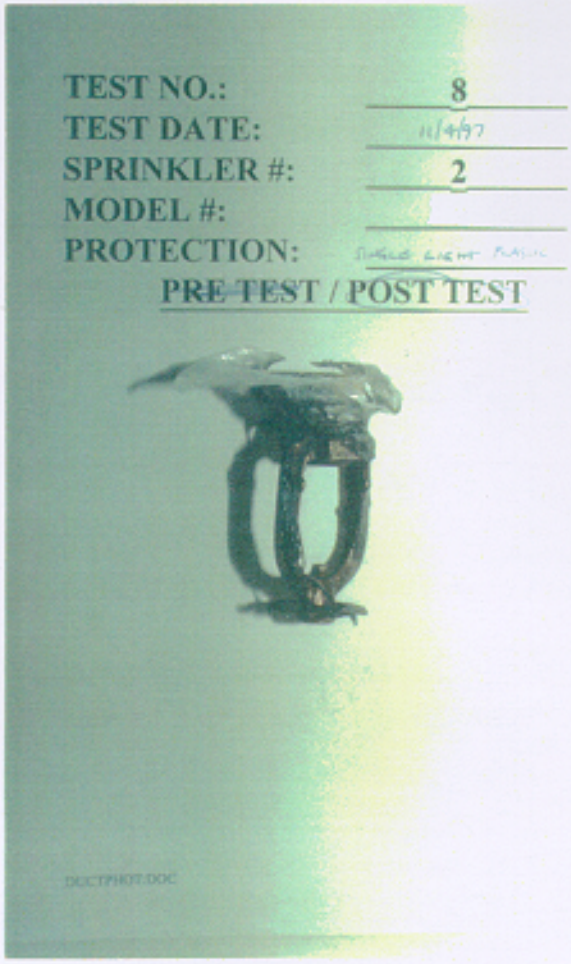


Figure 45 – Task 2:
Test #8, Post - test of sprinkler at position #2 showing the kick-out spring retained by a light plastic coating.

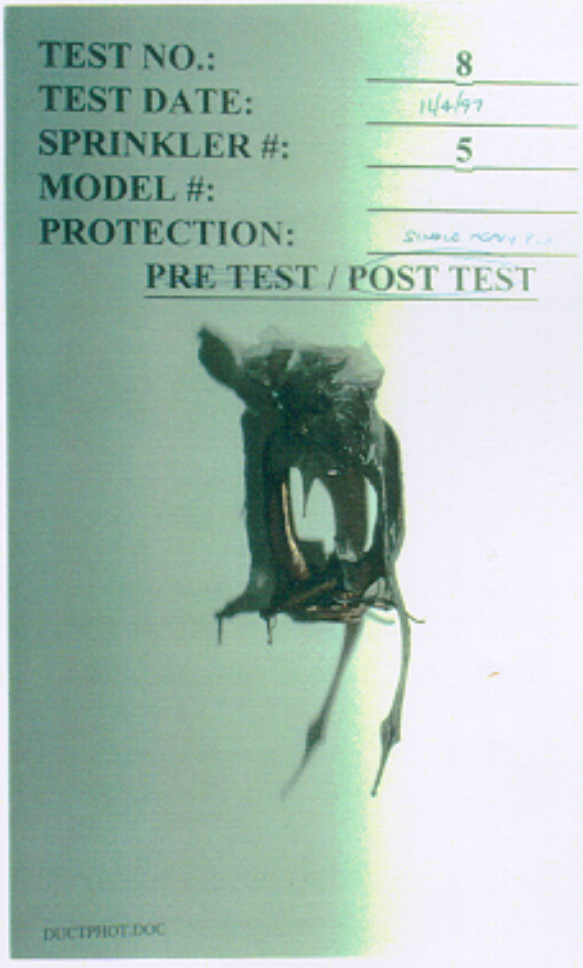


Figure 46 – Task 2:
Test #8, Post - test of sprinkler at position #5 showing the kick out spring, link and lever being retained by a heavy plastic coating.

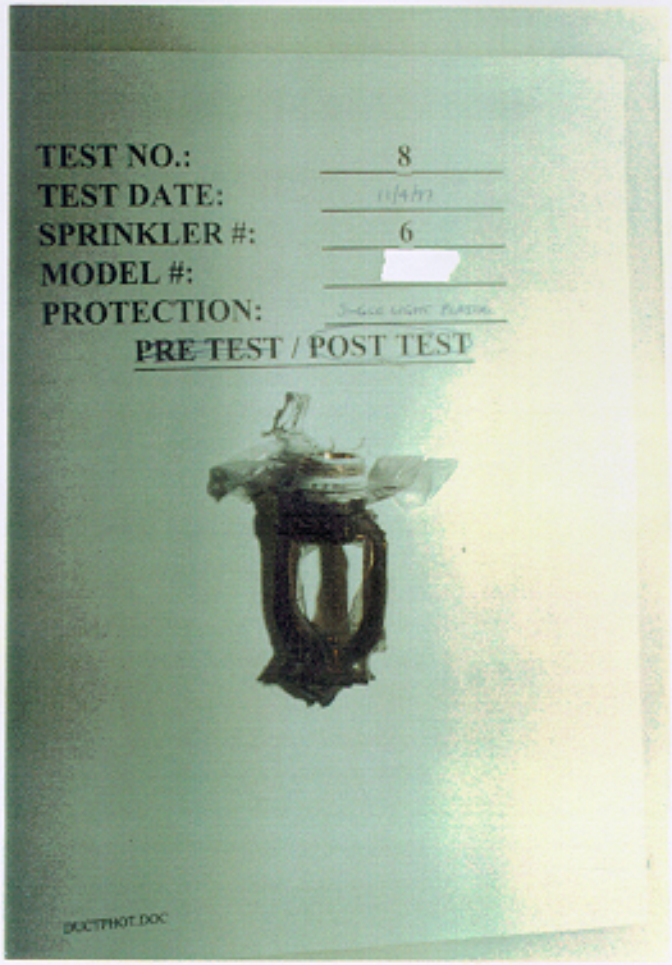


Figure 47 – Task 2:
Test #8, Post test of sprinkler at position #6, showing the plastic encasing the deflector and frame arms, however no parts were retained.

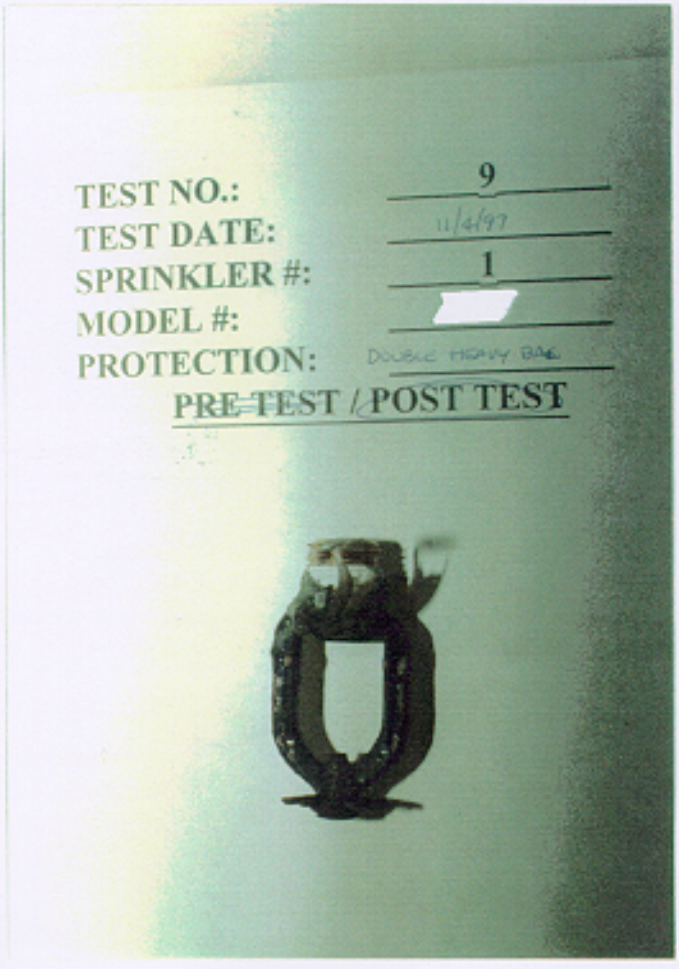


Figure 48 – Task 2:
Test #9, Post - test of sprinkler at position #1 showing the plastic had been removed almost completely and no parts retained.

Figure 49 – Task 2:
Test #9, Post test of sprinkler at position #2 showing the kick out spring being partially retained with a light coating of plastic.

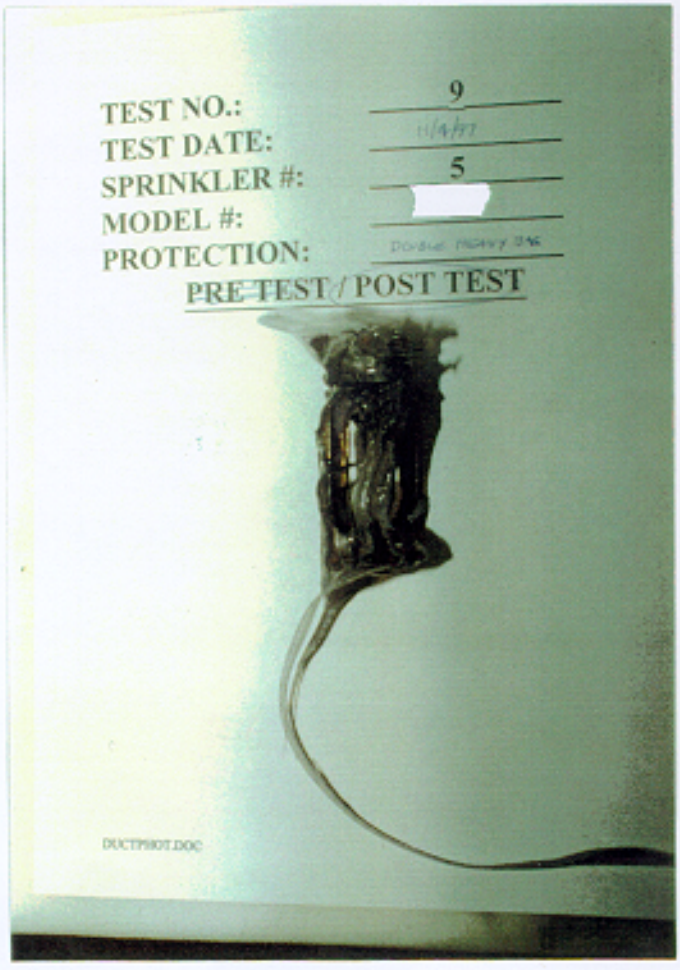


Figure 50 – Task 2:
Test #9, Post - test of sprinkler at position #5 showing the plastic encasing all of sprinkler except for part of 1 frame arm. No parts were retained (plastic extended ~9 in. below the deflector).

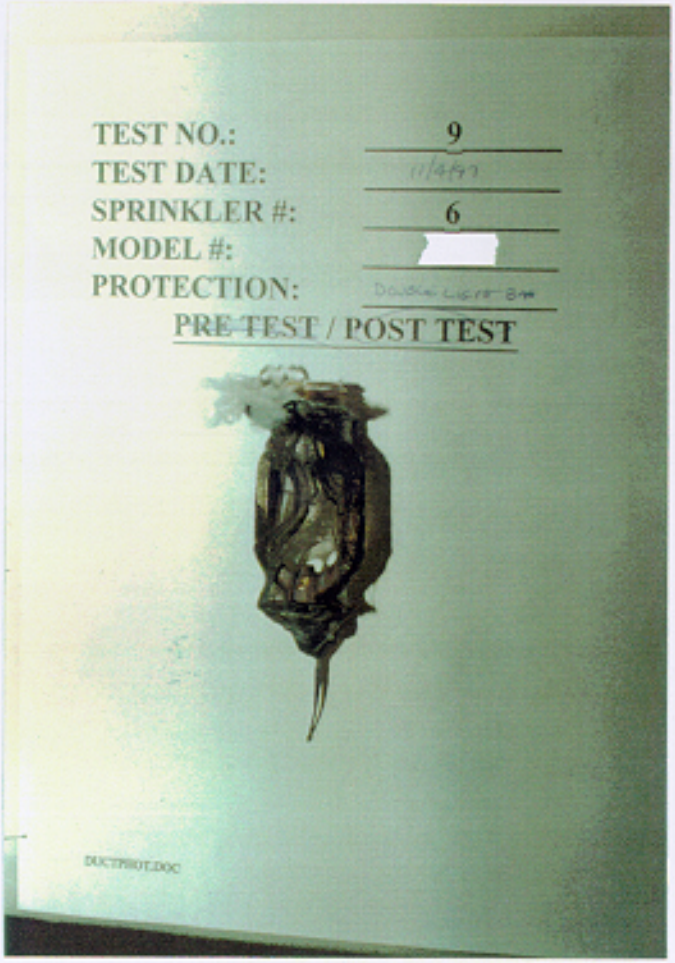


Figure 51 – Task 2: Test #9, Post test of sprinkler at position #6, showing the plastic encasing all of sprinkler except for part of one frame arm. Also, the plastic was blocking half of the water path The kick out spring was also retained.

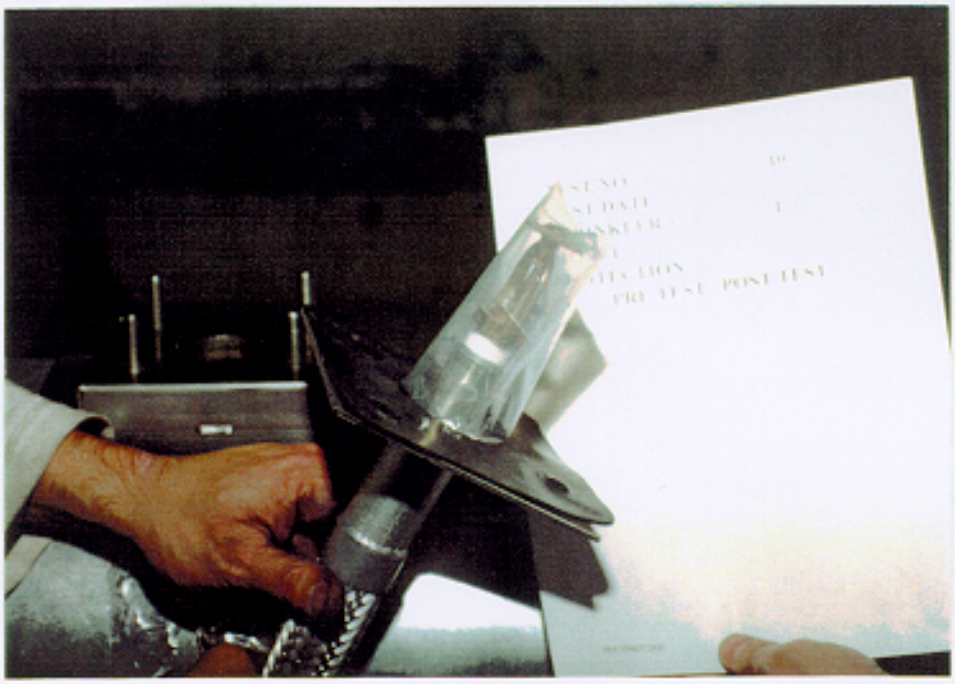


Figure 52 – Task 2: Test #10, Pre - test showing commercially available double bag / gasket assembly over an uncoated sprinkler attached to the flexible hose assembly (positions 1 and 6 had this assembly).

Figure 53 – Task 2:
Test #10, Pre - test showing double bag / gasket assembly on the inside of the duct fitting, (positions 2-5).

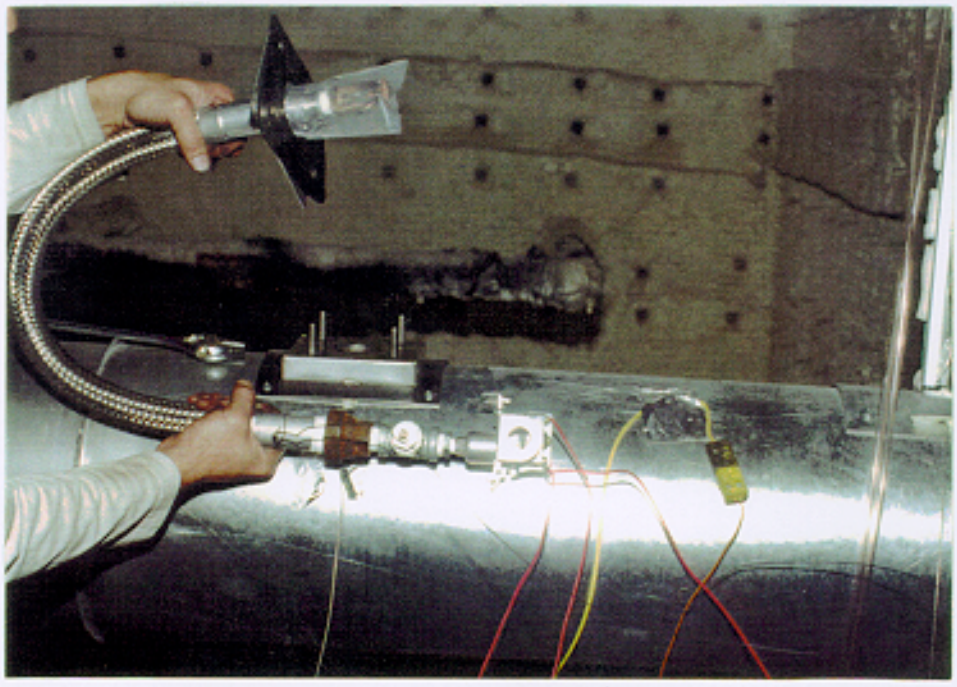


Figure 54 – Task 2:
Test #10, Pre - test of sprinkler at position #6 - commercially available flexible hose assembly attached to sprinkler.

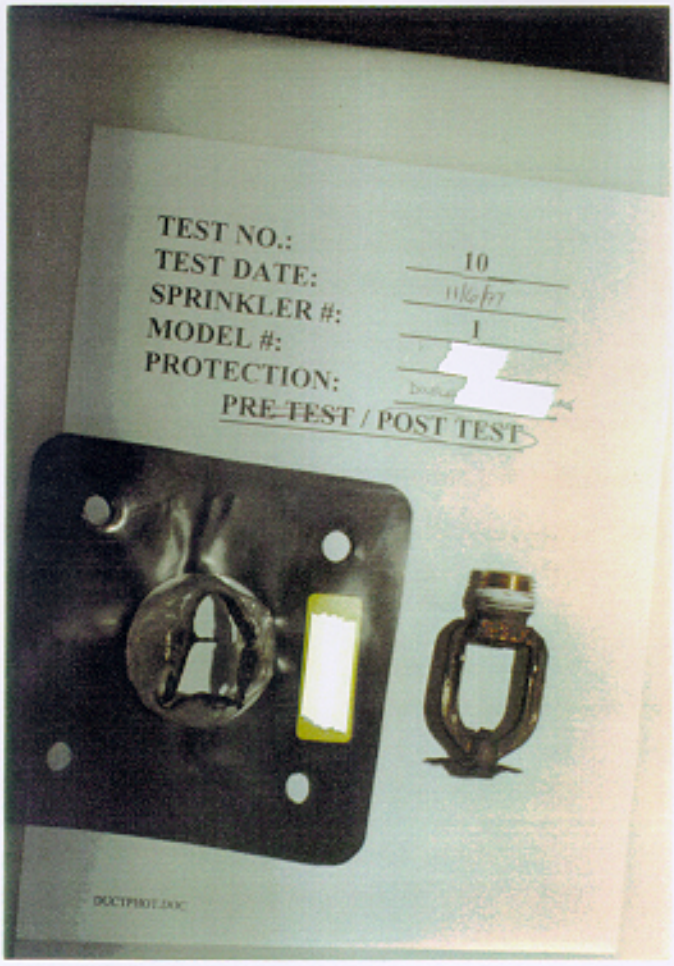


Figure 55 – Task 2:
Test #10, Post test of sprinkler at position #1, showing a thin coating of plastic on the sprinkler. No parts were retained and minimal damage to gasket was noted.

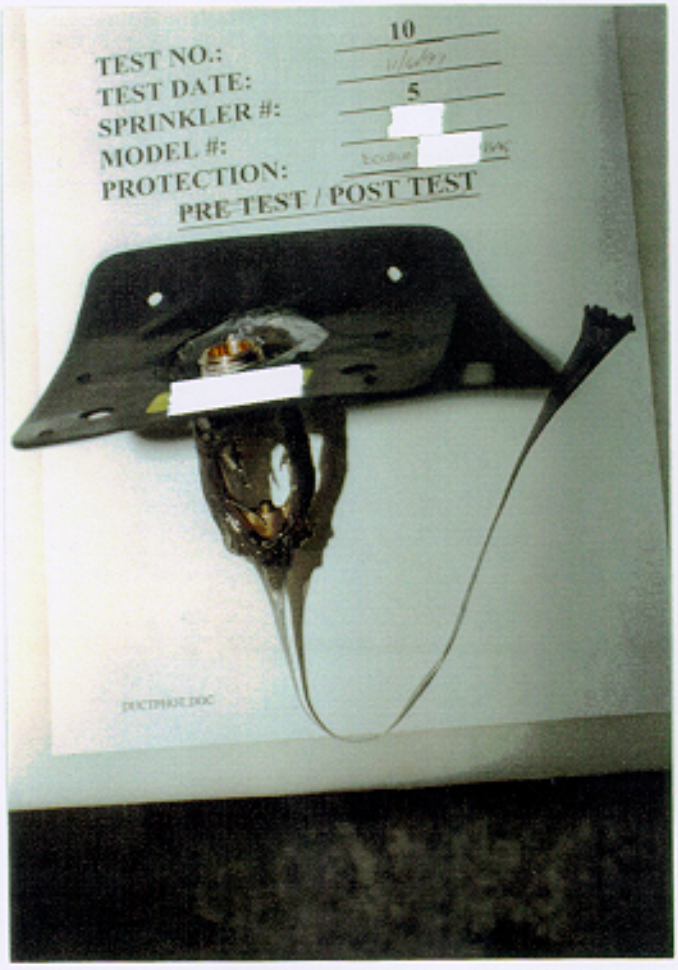


Figure 56 – Task 2:
Test #10, Post - test of sprinkler at position #5 showing the kick out spring being retained as well as most of the sprinkler being coated in plastic. The plastic material extended ~ 10 in. beyond the deflector. Also, the plastic retained the sprinkler to the gasket.

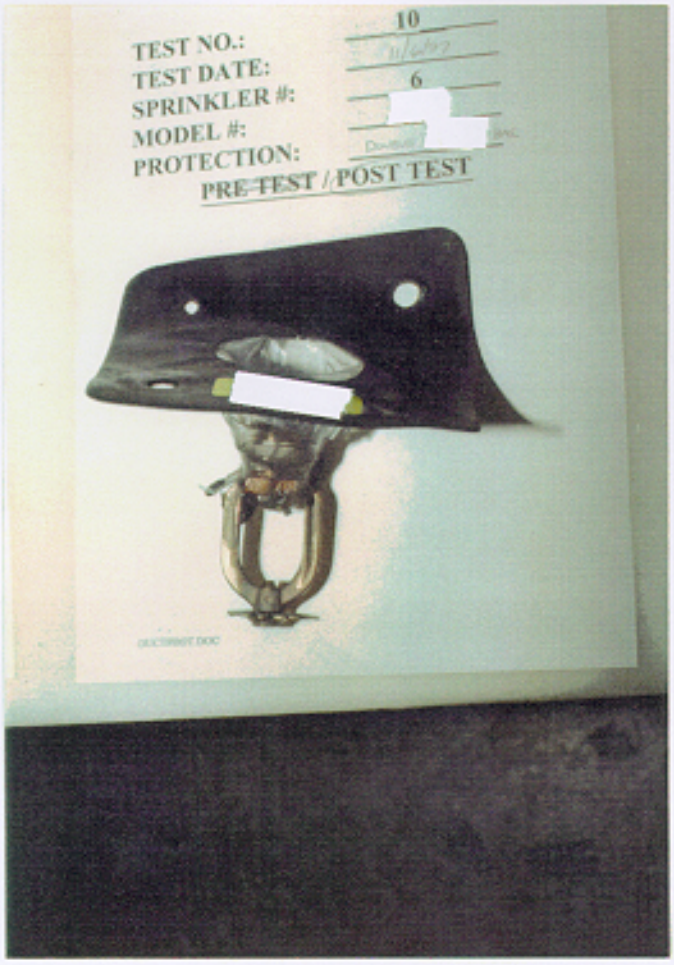


Figure 57 – Task 2:
Test #10, Post test of sprinkler at position #6, showing no parts were retained and the plastic bag only around the wrench flat and threads of the sprinkler.

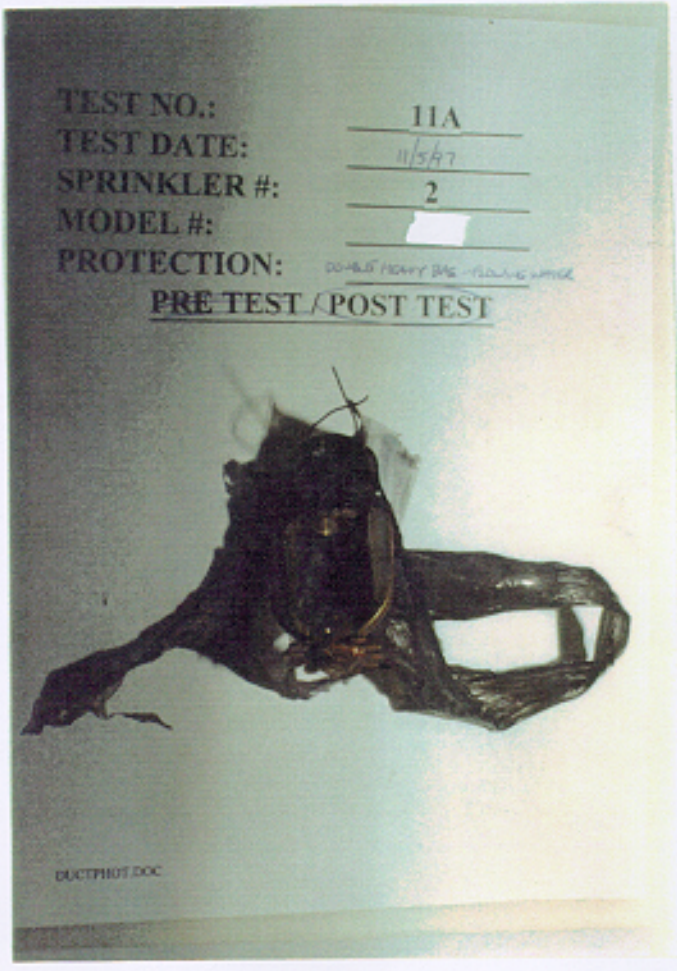


Figure 58 – Task 3:
Test #11, Post - test of sprinkler at position #2 (sprinkler flowing water). No parts were retained and the deflector and the frame arms were cleared of the plastic. The plastic was hardened.

Figure 59 – Task 3:
Test #11, Post test of sprinkler at position #4 (non-flowing sprinkler), showing the plastic encasing the entire sprinkler. The sprinkler never operated. The plastic was hardened.

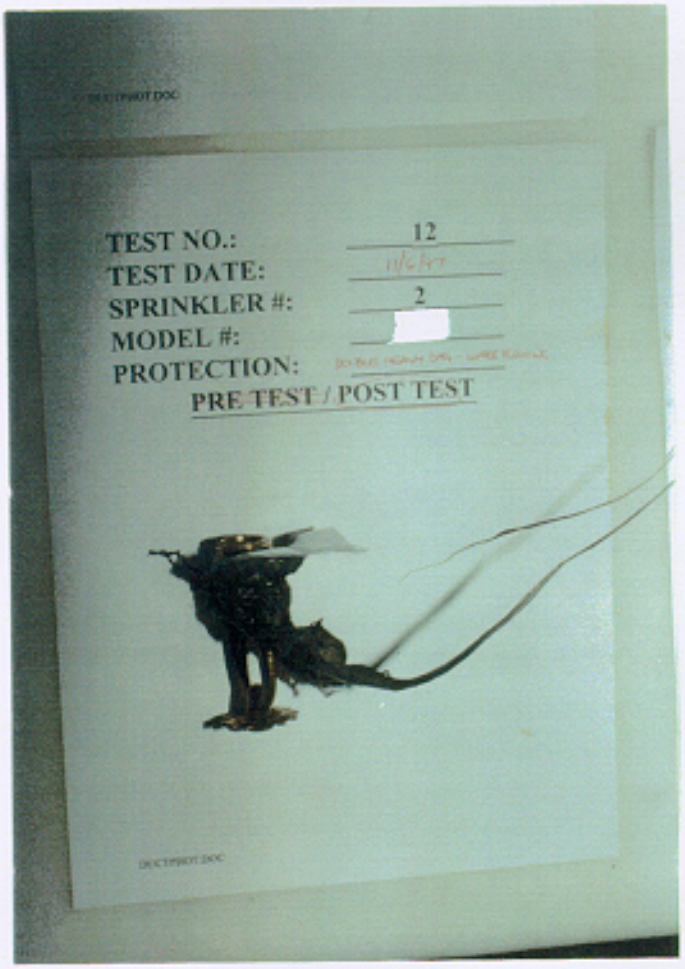


Figure 60 – Task 3:
Test #12, Post - test of sprinkler at position #2 (sprinkler flowing water), showing no parts were retained and the plastic clearing the frame arms and deflector.

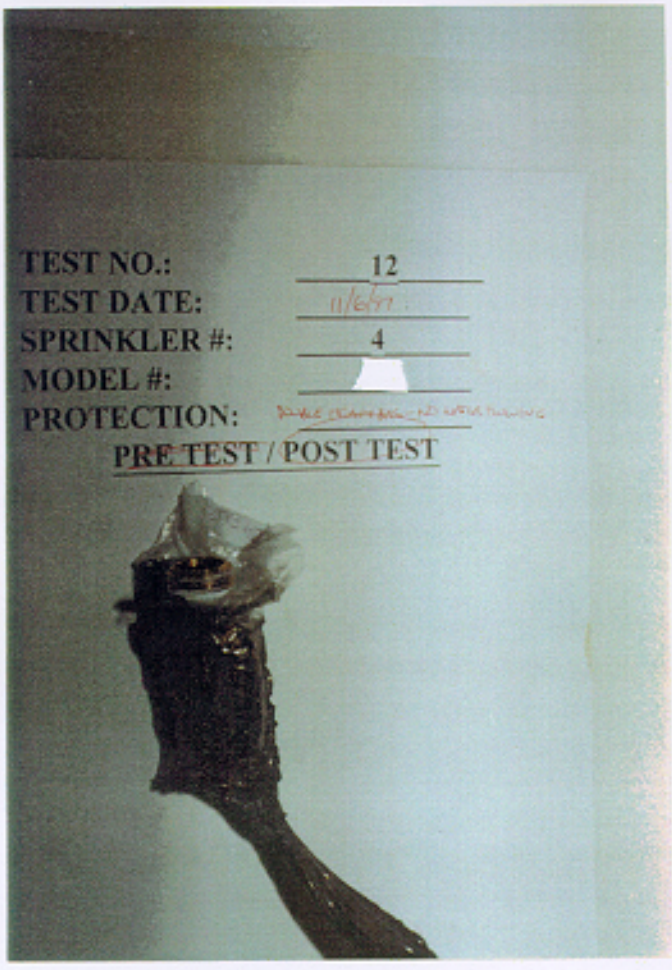


Figure 61 – Task 3:
Test #12, Post test of sprinkler at position #4 (non-flowing sprinkler), showing the plastic encasing the entire sprinkler. The sprinkler never operated. The plastic was hardened.

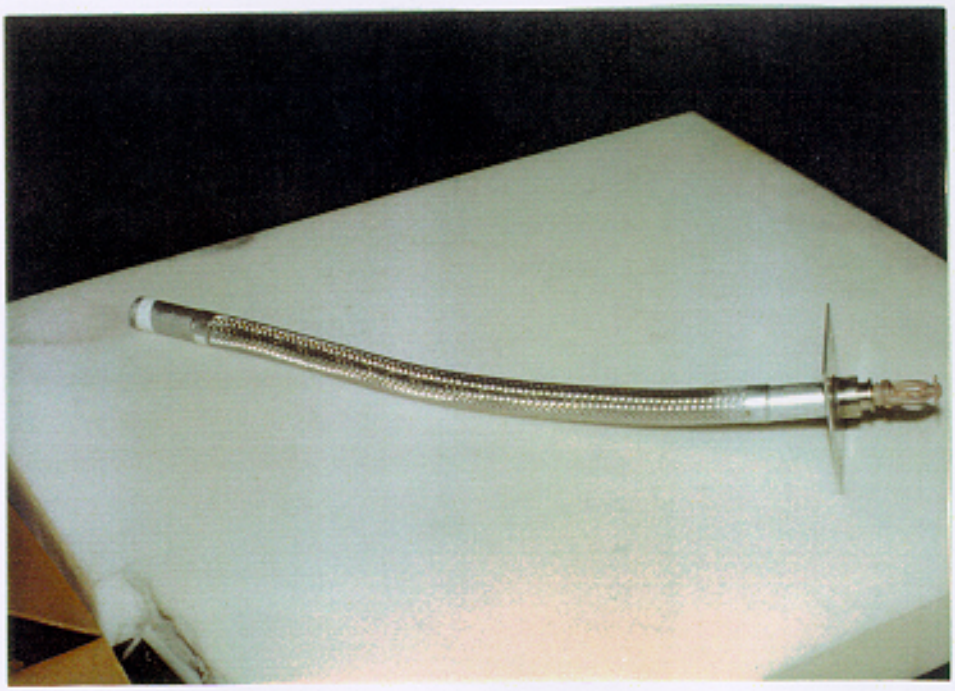


Figure 62:
Pre-Test Photo of commercially available flexible hose / corrosion resistant sprinkler product.

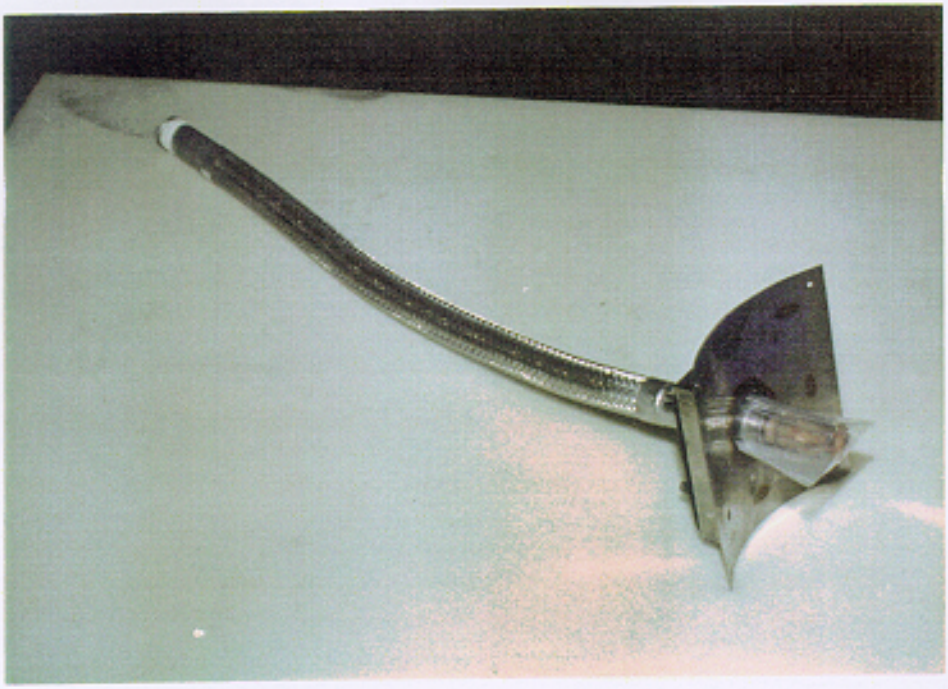


Figure 63:
Pre-test photo of commercially available flexible hose product attached to mounting plate with plastic bag / gasket assembly.

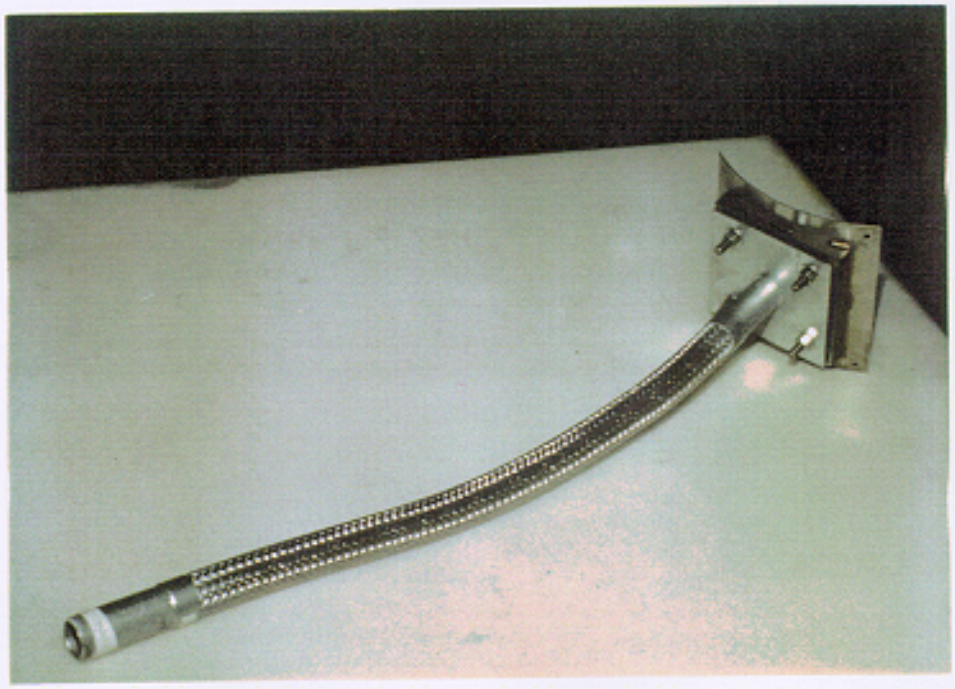


Figure 64:
Pre- test photo of commercially available flexible hose product showing top of mounting plate.

APPENDIX B

Temperature and Velocity Versus Time Graphs

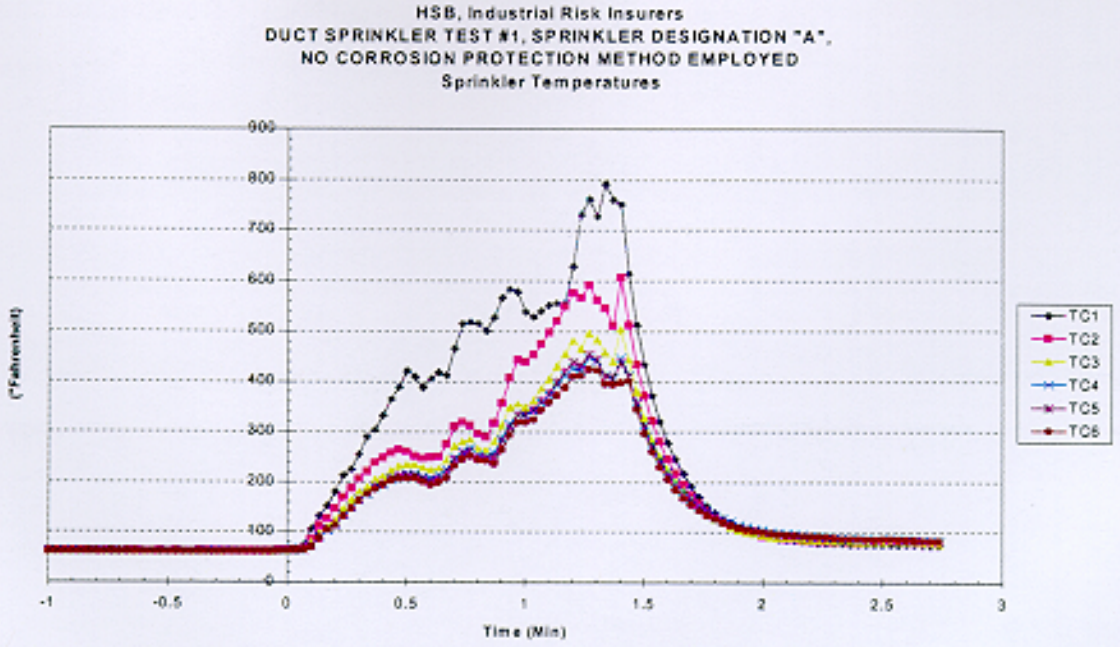


Figure 1. Sprinkler Temperatures

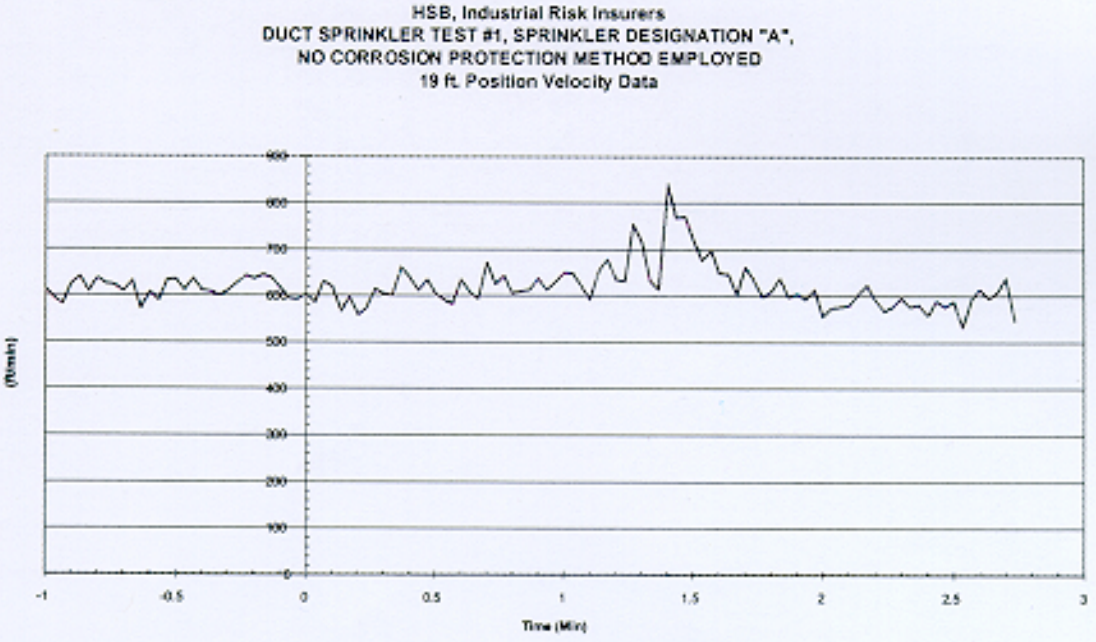


Figure 2. 19 ft. Position Velocity Data

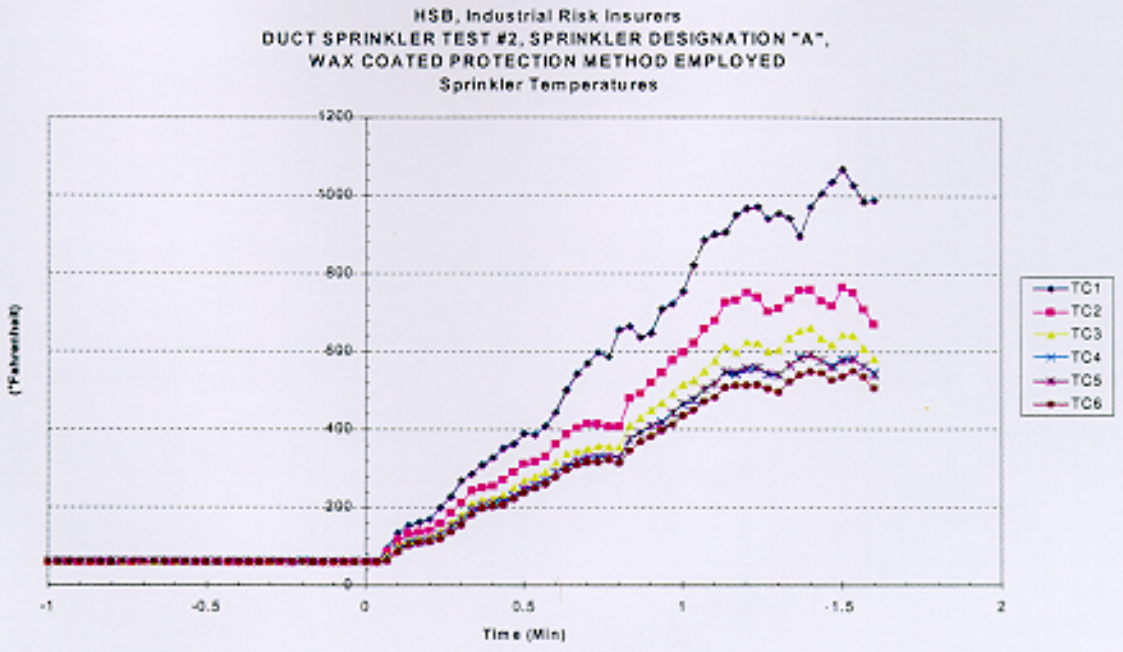


Figure 3. SPRINKLER TEMPERATURES

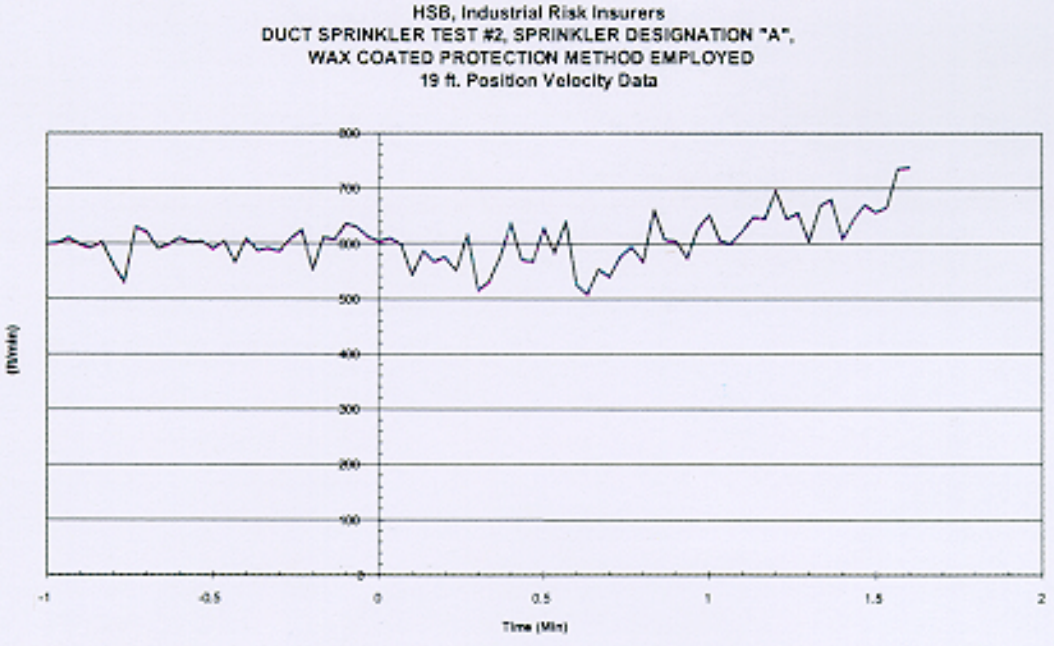


Figure 4. VELOCITY DATA

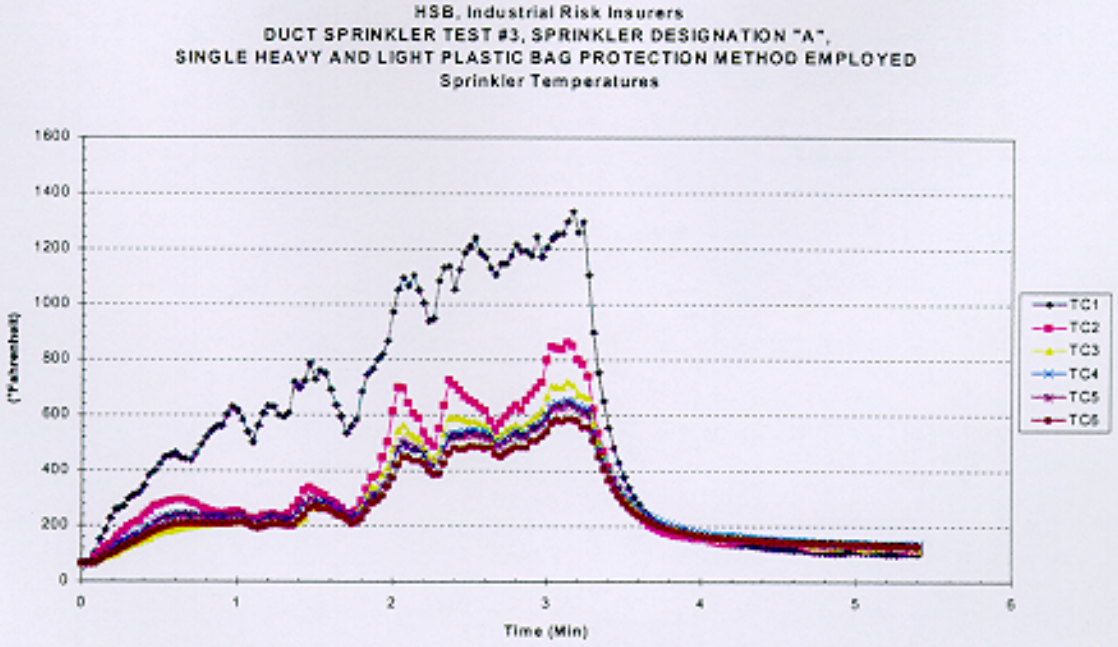


Figure 5. SPRINKLER TEMPERATURES

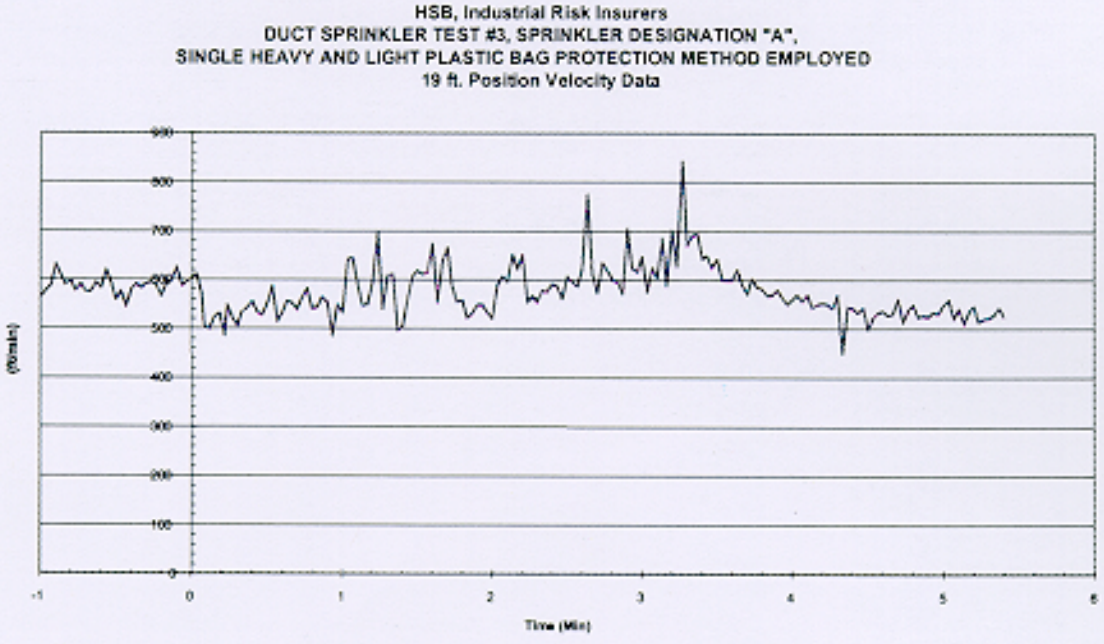


Figure 6. VELOCITY DATA

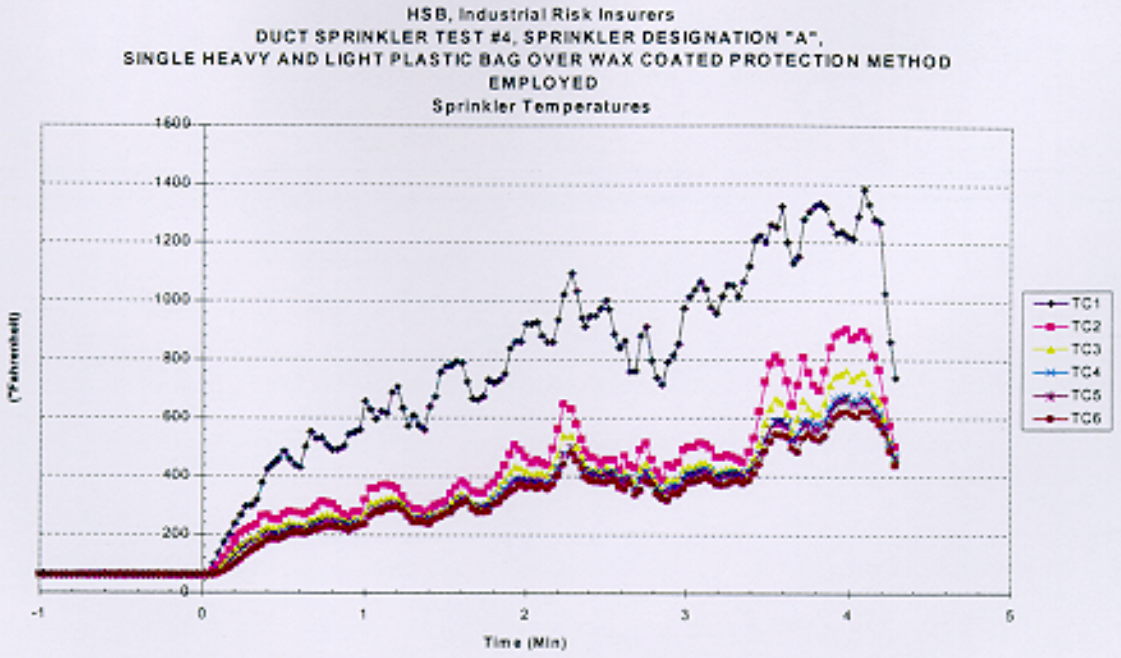


Figure 7. SPRINKLER TEMPERATURES

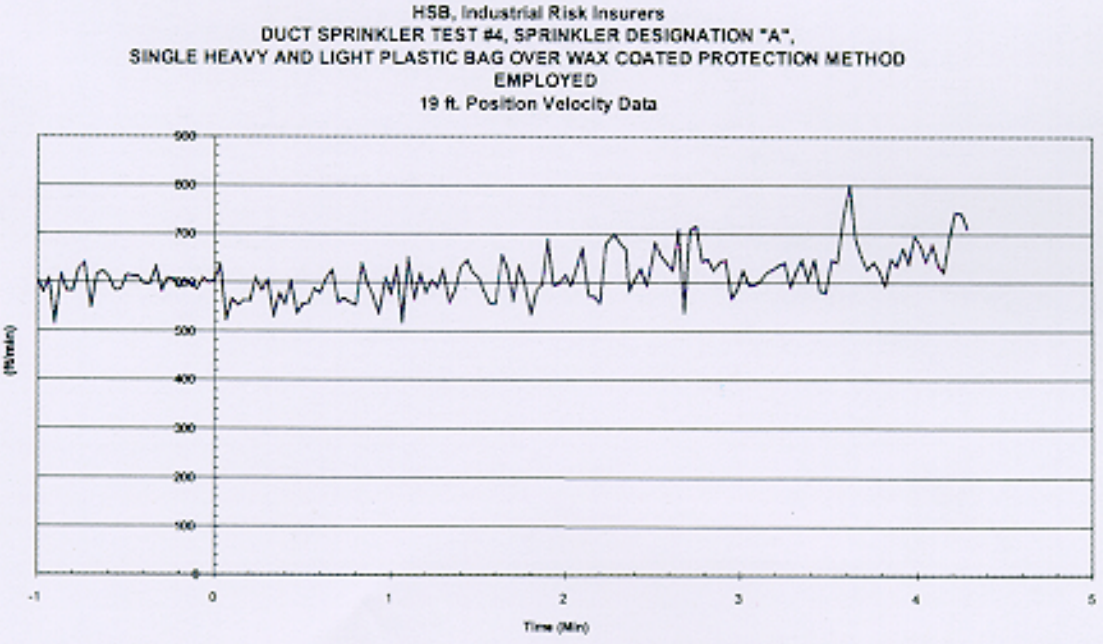


Figure 8. VELOCITY DATA

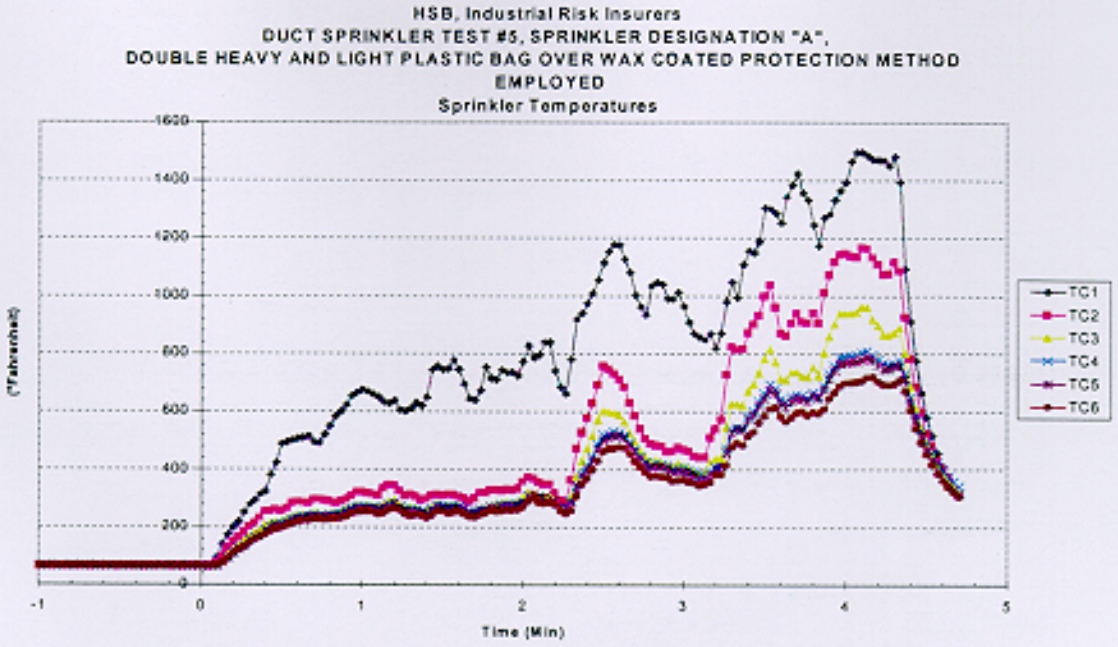


Figure 9. SPRINKLER TEMPERATURES

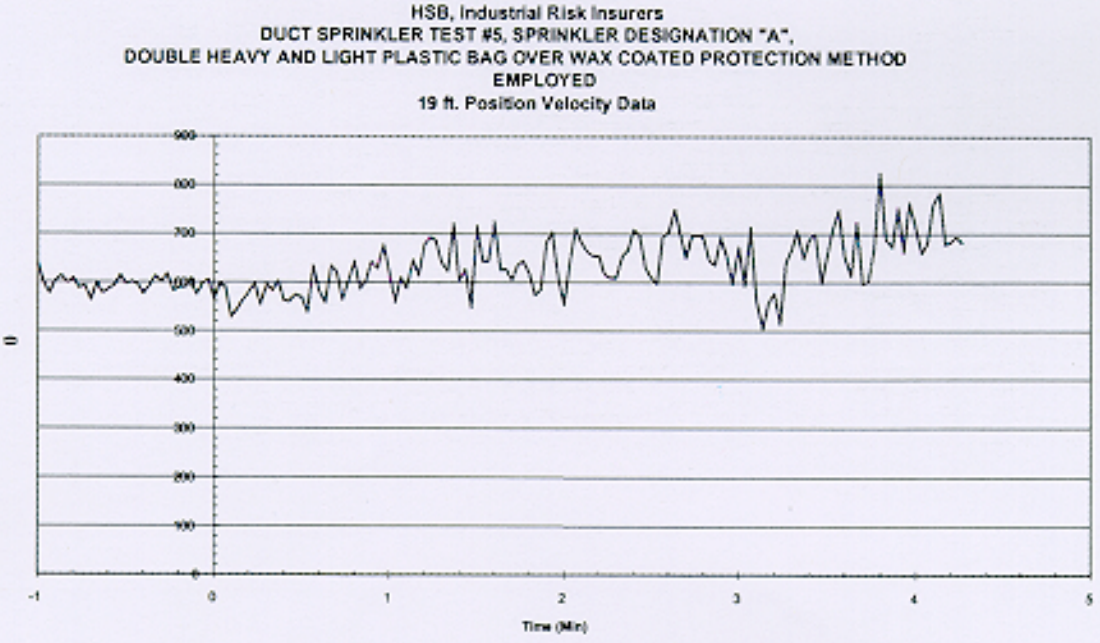


Figure 10. VELOCITY DATA

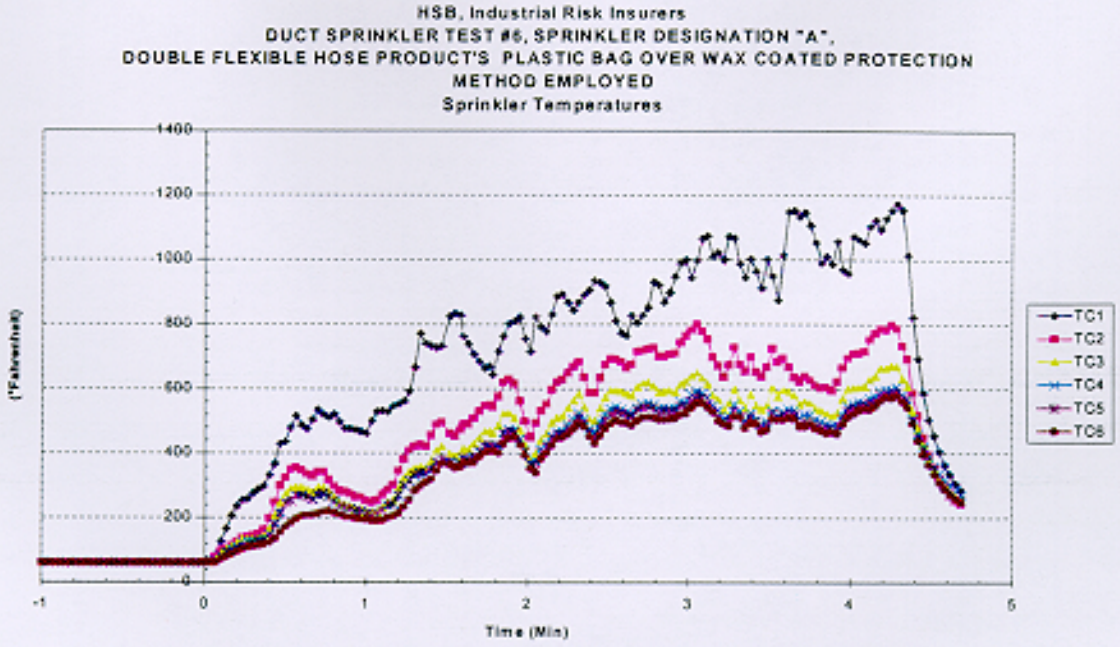


Figure 11. SPRINKLER TEMPERATURES

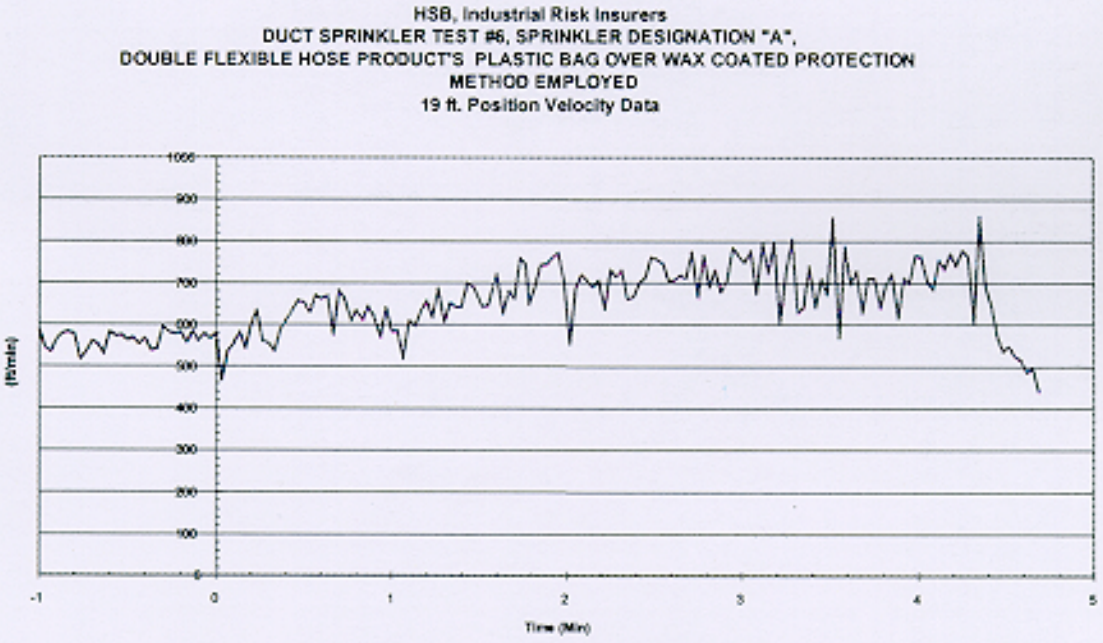


Figure 12. VELOCITY DATA

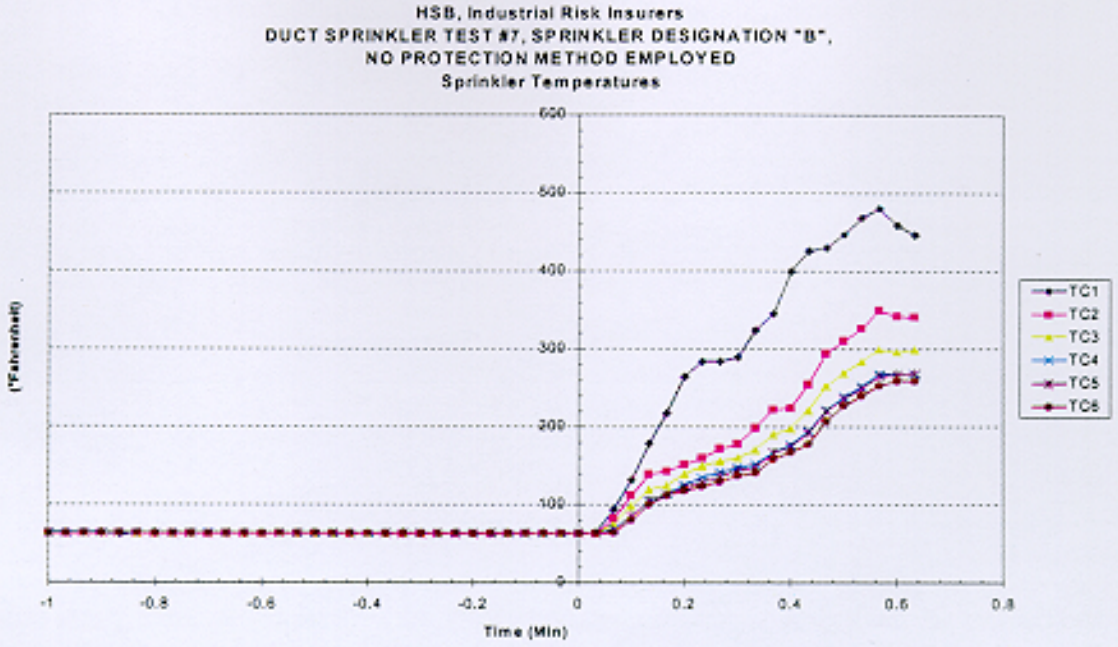
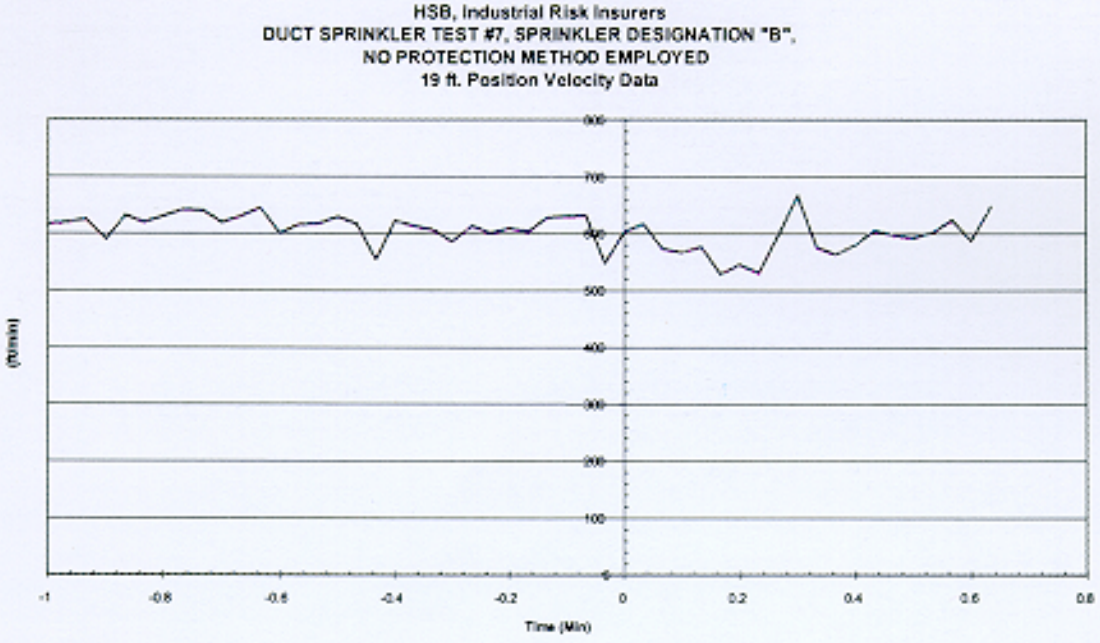


Figure 13. SPRINKLER TEMPERATURES



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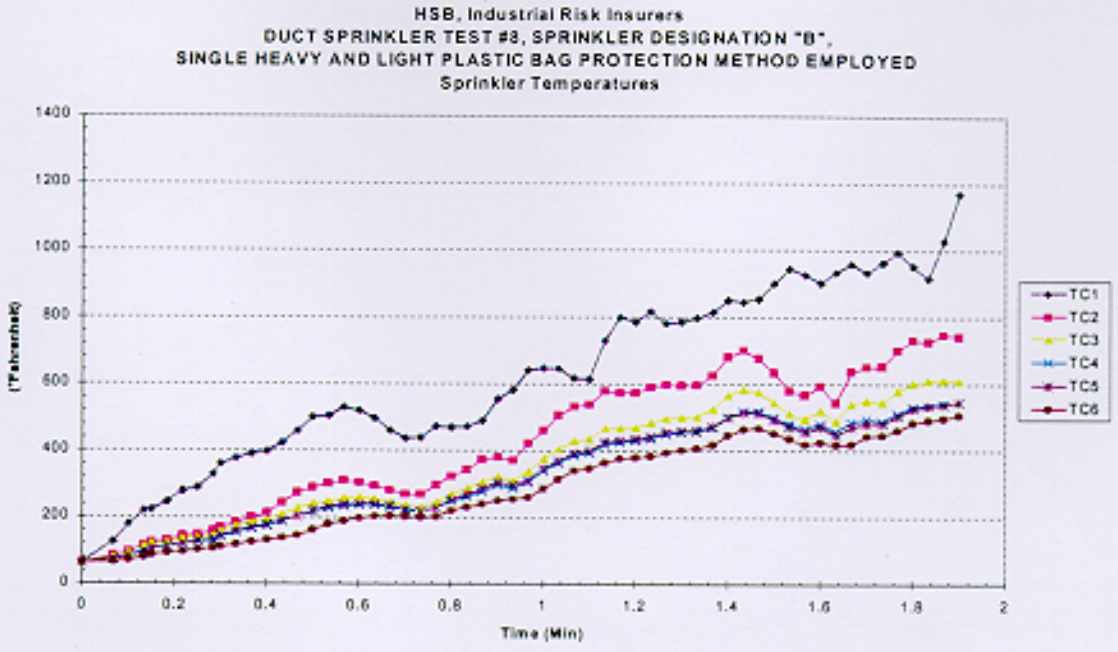


Figure 15. SPRINKLER TEMPERATURES

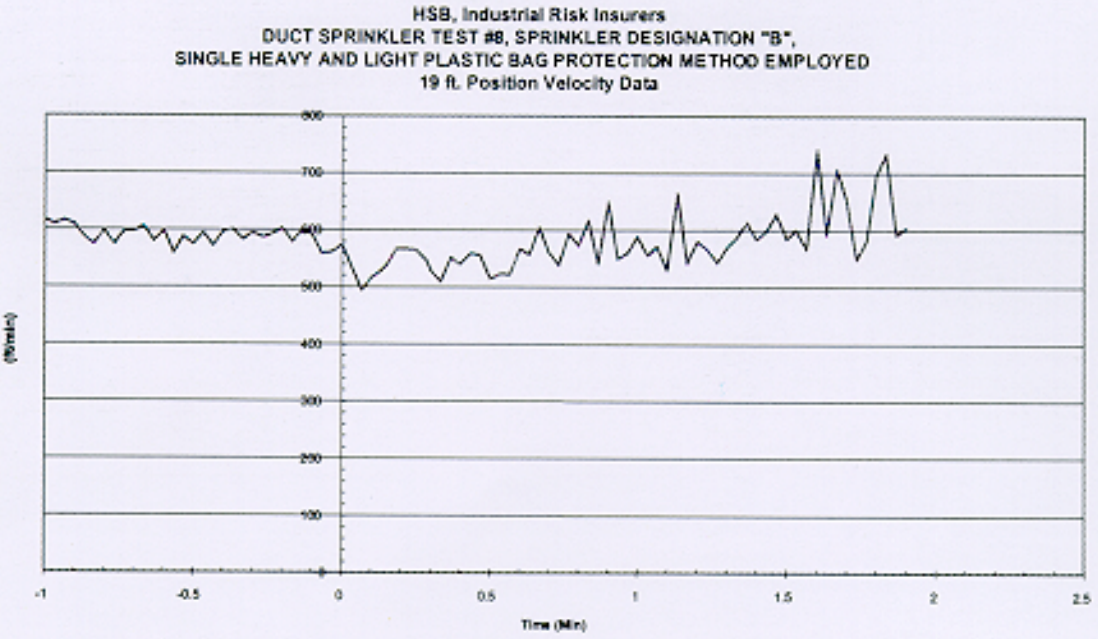


Figure 16. VELOCITY DATA

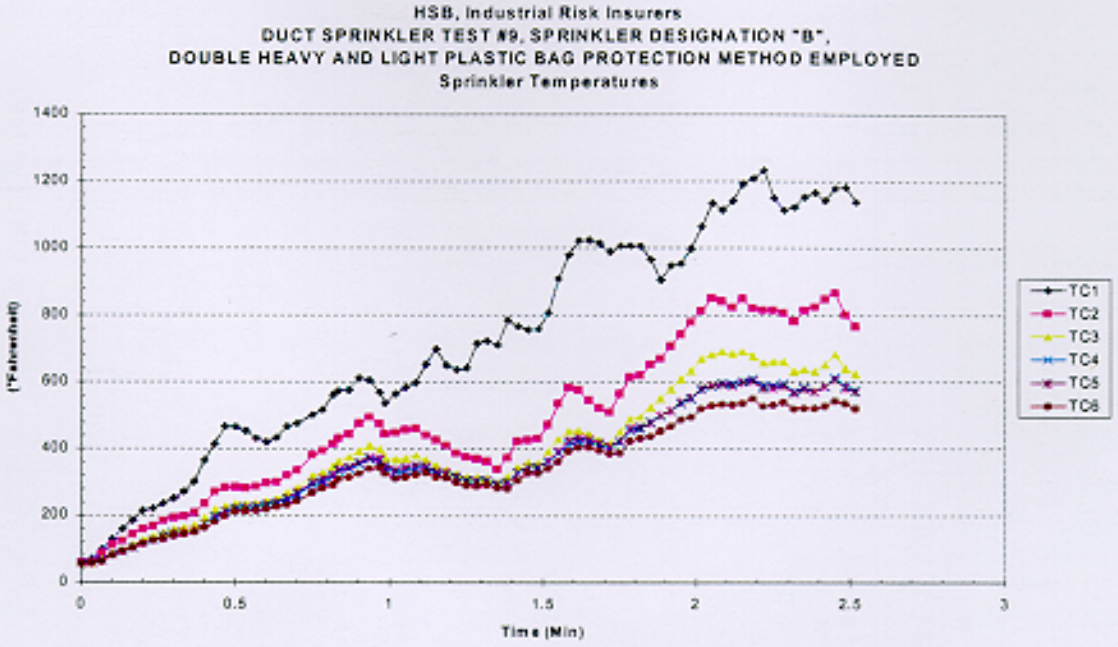


Figure 17. SPRINKLER TEMPERATURES

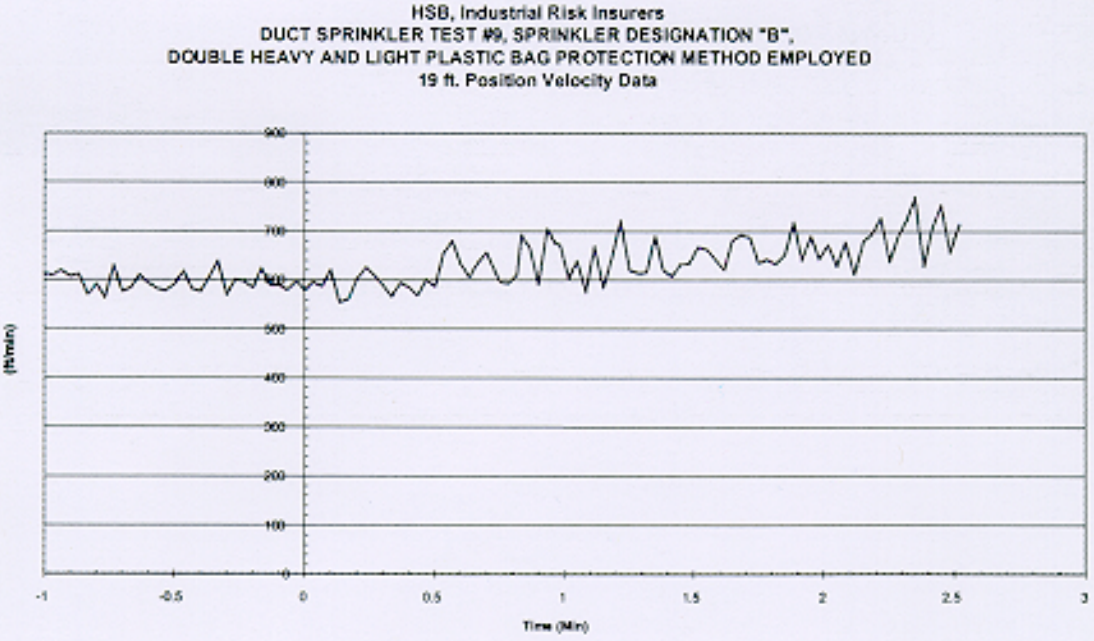
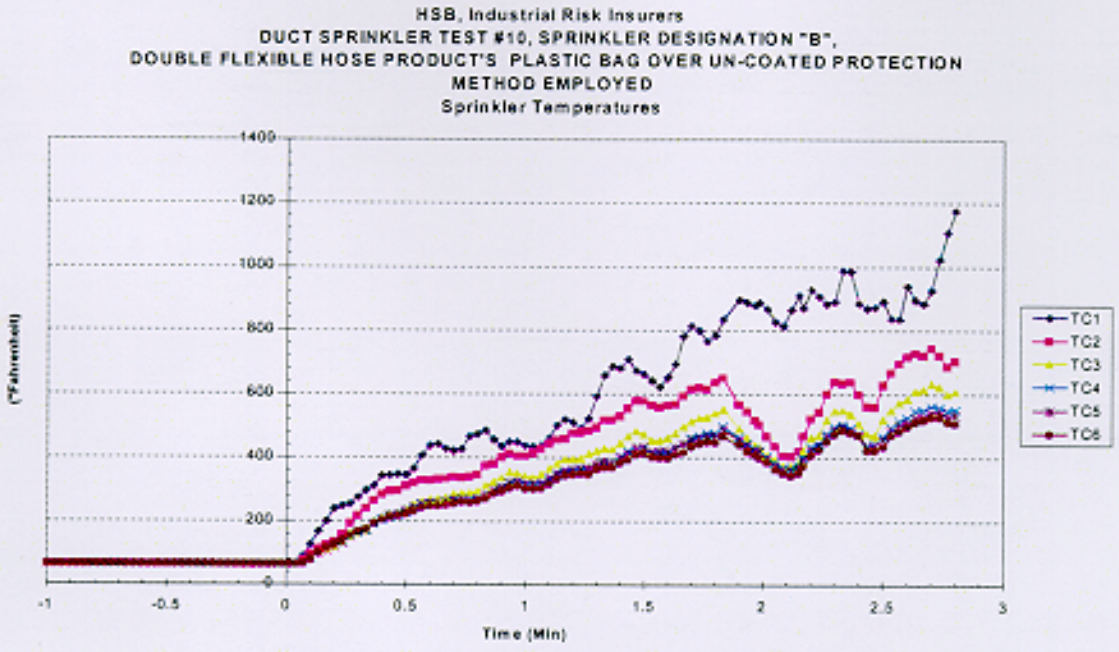


Figure 18. VELOCITY DATA



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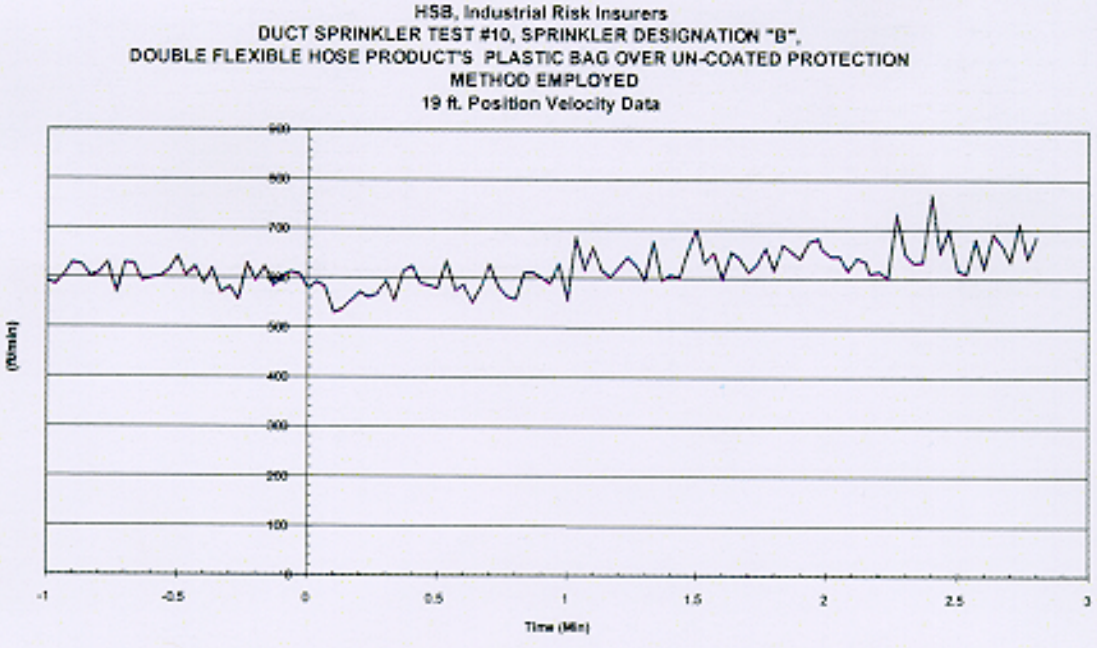

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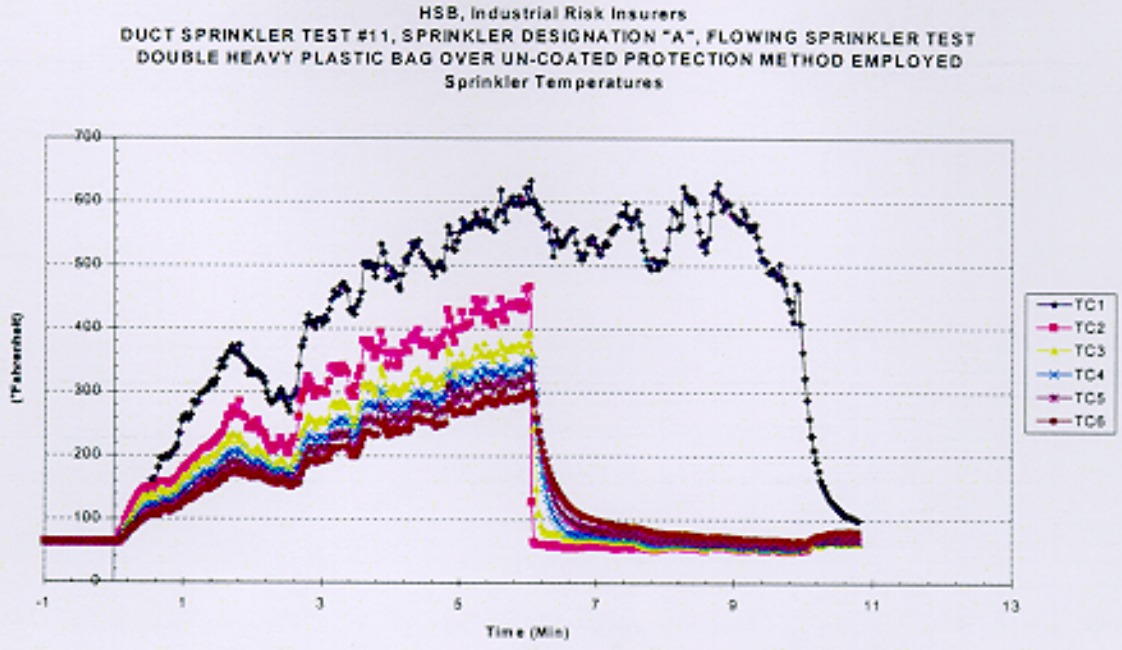
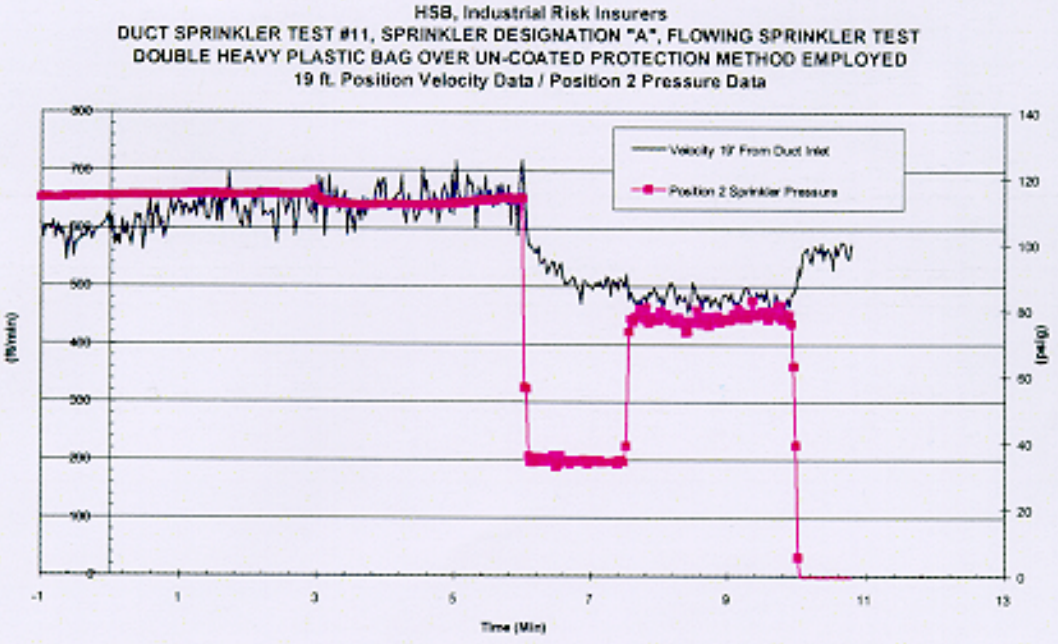


Figure 21. SPRINKLER TEMPERATURES



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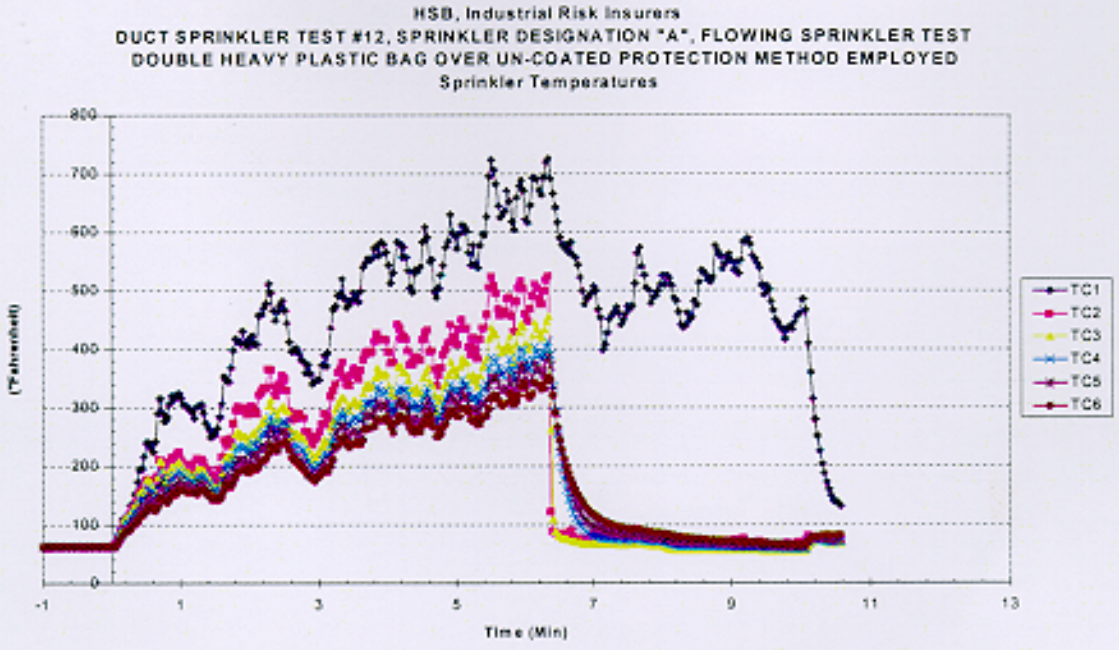

Figure 23. SPRINKLER TEMPERATURES

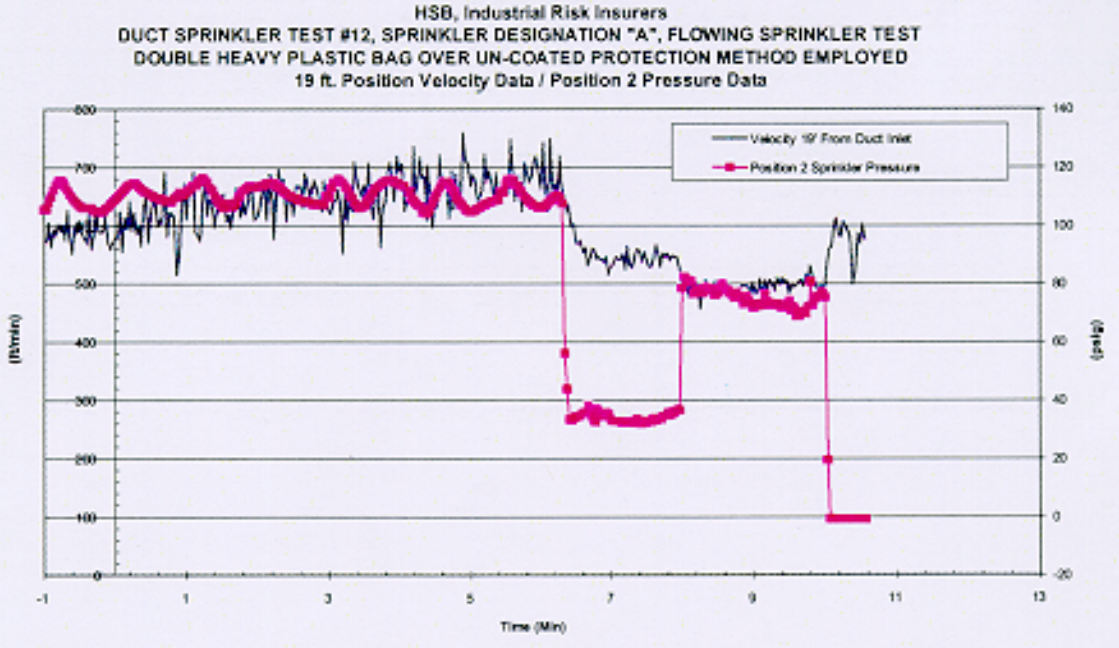

Figure 24. VELOCITY DATA